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ABSTRACT

This guide, prepared by the Oklahoma State Department of Education, is designed to assist administrators, their staffs, and science teachers for grades K through 12 to assess and improve their science programs. Topics discussed include: (1) the relationship of science to the total school program, (2) the unity of science, (3) the nature of inquiry, (4) the nature of the learner, (5) a basic philosophy for a science program, (6) purposes of science education, (7) safety, (8) evaluation without tests, (9) developing a science program, and (10) activities that support science education. (SL)

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THE IMPROVEMENT OF SCIENCE INSTRUCTION IN OKLAHOMA

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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OKLAHOMA STATE DEPARTMENT OF EDUCATION

Leslie Fisher, Superintendent

1978

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"The cover logo represents a signaling of new birth, a continuing process, a vitalizing of learning, and the opening of a beginning." — *Larry McKinney*

The Improvement of Science Instruction

In

Oklahoma

(K-12)

Prepared by
State Science Committee
of the
OKLAHOMA CURRICULUM IMPROVEMENT COMMISSION
E. Joe Sharp, Chairman

under the auspices of the

CURRICULUM SECTION
Clifford Wright, Administrator
Earl Garrison, Administrative Officer

and
Larry McKinney
Science Specialist

OKLAHOMA STATE DEPARTMENT OF EDUCATION
Leslie Fisher, Superintendent

1978

FOREWORD

The impact of science on the modern world is probably greater today than any time in history. It is important that our young people must have a thorough understanding of the basic principles of this subject.

The failure to make science relevant to modern day living is probably one of the reasons that it is not grasped with the same degree of enthusiasm by the students as other courses. Our science program must be modernized in such a way that our children can understand the basic principles involved in this field.

With the explosion of discoveries in new areas of scientific knowledge and the rapidity of progress in recent materials and innovative teaching methods employing diversified techniques, it was felt there was an imperative need to publish a science guide K-12.

It is hoped that teachers will find this guide useful in providing the kind of science program that will be most beneficial for the young people in Oklahoma. This material promises to be a useful resource for all the teachers in Oklahoma.

The State Department of Education appreciates the continuous efforts of those who have in any way contributed to improving the teaching of science in our schools. We wish to thank those who gave so freely of their time and talent in developing the material in this booklet.

Leslie Fisher
State Superintendent

ACKNOWLEDGMENTS

The State Science Committee is indebted to the science teachers of Oklahoma for their cooperation and contributions toward the completion of this comprehensive K-12 Science Curriculum Guide. Local teachers, administrators, and university professors all have contributed to the improvement of science instruction in Oklahoma schools.

The small group of science teachers who last met to provide final directions for the guide were: Martha Nell Dodson, Richard Bryant, Barbara Leeper, John Roller, and Eugene Smith. Contributors of major portions of the guide were: M.C. Weber, John Renner, Quinten Polk, Ed Stoever, Jr., Don Stafford, and Talbert Brown.

As this guide is a compilation of all the successful portions of The Improvement of Science Instruction in Oklahoma: Grades 1 through 6 and The Improvement of Science Instruction In Oklahoma Grades 7 - 12 and of additional contributions, the guide should be dedicated to all science teachers who directly worked on the guides and to science teachers who directly influenced those who made contributions.

This publication, printed by the Latimer County News-Tribune, Wilburton, Oklahoma is issued by Oklahoma State Department of Education as authorized by Leslie Fisher, State Superintendent of Public Instruction. 5,000 copies have been prepared and distributed at a cost to the taxpayers of the state of Oklahoma of $4,150.90.

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INTRODUCTION

THE NEED FOR A CONTINUOUS K-12 SCIENCE PROGRAM

In an educational continuum K-12, the elementary child should have opportunities to develop the intellectual processes essential to learning and to understanding science. In the process of skill development, children will acquire an understanding of the basic science concepts necessary for the interpretation and explanation of observations and natural events. The children will also have experience in using these science processes and become more independent and self-sustaining in their learning.

The middle school program, primarily concerned with students between the ages of 11 and 15, should provide those educational experiences most suitable to their state of development, concerns, needs, interests, and social responsibilities. The program should not revolve around a single text, medium, or preparation for high school; instead, it should include those materials that are best able to communicate with these children and most consistent with their educational needs.

The high school curriculum should provide opportunities for each student to explore many areas of science. The science program should be designed to help each student attain his own highest potential, to experience success, to become more independent, and to accept greater responsibility for his own education. Recently chemistry and physics enrollments have dropped alarmingly. New programs and short courses which would provide greater options more relevant to the needs and concerns of the students should be considered, so that all students may attain some degree of scientific literacy.

There must be a change in emphasis from teaching to learning, from memorizing to understanding, and from a threatening environment to one characterized by freedom to explore, discover, and pursue knowledge that has real meaning. School programs which have been developed with these aims should be examined carefully and chosen on the basis of the needs of the children and the community.

At present, many school systems have no clear goals for their science program; therefore, each teacher works independently within the monetary and educational limit of the school. To provide the best opportunities for the children, it is essential that each community have a science advisory committee who will assess the needs of students, will examine available programs, and will then plan for implementation within their school systems. Without a local science consultant, it's especially important that representative teachers from each school should work together to develop a coordinated science curriculum.

Few elementary and middle school teachers are prepared by their education to teach science. Most educators will follow the example of their own teachers. Few have been exposed to processes of science and inquiry techniques essential to many new science programs. Even with the best preparation, it is unlikely that teachers can do an effective job with the inadequate financial backing, the inadequate physical facilities, and the excessive work load under which many struggle. If any science program is to be successful, teachers must have the psychological, professional, and monetary support of the administration and the school district.

This guide is not intended to be the "final word" in science education. As we continue to learn more about different modes of learning and as newer and better materials are developed, we must change. We must change because what we do today is based on what we now are aware of. What we do next year should therefore be different. This means continued reassessment and updating of instruction and retraining of teachers. It is hoped that this guide will serve as an instrument which will assist administrators and their staffs to assess and improve their science programs.

CHAPTER I

WHAT IS SCIENCE EDUCATION?

RELATIONSHIP OF SCIENCE TO TOTAL SCHOOL PROGRAM

It has been stated that the purpose of education is to develop the rational powers and that science is a natural vehicle to foster this development. This chapter identifies the role of science as it relates to the total school curriculum, the nature of the intellectual development of the child, and the role of science in relation to the child's cognitive processes.

In recent years, curriculum projects have been developed which are based upon the principle that the disciplines themselves serve as the basis for the selection of the content. Examples of those curricula have been presented in another chapter. As a result of these projects, there is an emerging trend that is concerned with the total structure of the knowledge and its implications; that is, many disciplines have a common method by which the content is studied.

Phenix[1] suggests for the selection of the content of the curriculum in general four basic principles:

(1) The content of instruction should be drawn entirely from the fields of *disciplined inquiry*.

(2) From the large resources of material in any given discipline, those items should be chosen that are particularly *representative* of the field as a whole.

(3) Content should be chosen to exemplify the *methods of inquiry* and modes of understanding in the disciplines studied.

(4) The materials chosen should arouse imagination.

In light of the foregoing principles, what is the relationship of science to the total school? Elementary school science can make a significant contribution to the education of *all* children. The role of science in the elementary school is one which encompasses the teaching of the ability to think. Due to the nature of the discipline, science becomes a natural vehicle to aid their rational development. The unifying theme is the teaching for inquiry and discovery.

Teachers have a responsibility for introducing the student to the scientific world as it exists, and any attempt to conceal its true nature from

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[1] *Philip Phenix, Realms of Meaning. New York: McGraw-Hill Book Co., 1964, p. 10-12.*

the student for the sake of expediency is unfair to science, unethical on the part of the educator, and extremely damaging to the student when he eventually and inevitably finds that he has been misled. The inquiry approach to science instruction will give the student insight into what science is.

Another important point is that scientific inquiry involves freedom of creativity, but within an orderly and logical framework. One basic value underlining creativity is independence. Whether that creative act be in science, literature, mathematics, music, or art, "a man must see, do and think things for himself."[2] If in the elementary classroom, a child is allowed this "freedom of mind,"[3] is it not logical that he will develop a more creative attitude? Futher, if a child is allowed this freedom to inquire, he will develop a more sensitive appreciation for the values underlying a democratic society. For example, *dissent is the mark of freedom* and dissent is a value in our democratic society. But if we have dissent in society and science, we must also develop tolerance. This is to say that in this type of environment an individual should develop self-discipline and a responsibility for one's actions. These values of *"freedom of mind, dissent, tolerance, and self-discipline cannot be developed in an authoritation, dogmatic, rigid classroom."*

As teachers, we must be concerned with the total individual, and knowledge as a whole. We must teach science as a part of one's life--socially, politically, economically, and aesthetically. It is not something taught just to develop a "brain trust," but as a part of one's life experiences. Science then, should be closely allied to the other disciplines which make up the elementary school curriculum. For example, students should be introduced to the use of mathematics in their science studies. Mathematics should be treated as an integral part of the scientific discipline not isolated as a separate and distinct subject. The student in the elementary discipline should be introduced to basic statistical methods in handling data such as histograms, graphs in two dimensions, and their implications. The learner should deal with making measurements and interpreting these quantitative data. The teacher should capitalize upon the various relationships in terminology between the two disciplines. This is the way in which man has discovered order in nature. Historically, science methods did not progress until mathematics was used to explain the basic laws of the physical universe and to order and interpret biological data.

Communication skills may also be developed during the science program. In utilizing inquiry, the child will develop the ability to write the

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[2] Jerome Bruner, *The Process of Education*, (New York: Vintage Books, Random House, 1960), p. 12.

[3] J. Bronowski, *Science and Human Values*, (New York: Harper Torchbook Series, 1956), p. 9-32.

results of experiments, report observations and measurements, and discuss activities with his peers and with the teacher. Many times during inquiry the child may develop a need to read about a particular phenomena and this should be encouraged. In developing the idea of classification, a child must learn to discriminate. Discrimination of symbols and words is also important in learning to read. There are many areas in which the study of science and language art skills are compatible.

It becomes necessary that a school system which adopts the inquiry approach to teaching science, continue the program through junior and senior high school. The function of elementary science in relationship to junior high science is to set the "emotional tone" for further science study. Using the inquiry approach will extend the natural curiosity of the child. The natural curiosity of the child when he enters junior high school is often depressed to the point that he will not learn and has lost interest in science. Learning early to appreciate and enjoy science and the work of scientists in this technological age will stimulate the child to wish to continue to learn science in the junior and senior high school as an integral part of his basic education.

An attitude of inquiry is basic to the nationally developed science studies in the secondary curriculum. *The elementary teacher should not be concerned with a set of content prerequisites for the secondary school program but rather be concerned with developing attitudes of inquiry so that a child's search for knowledge may be extended.* On the other hand, secondary school teachers should understand the nature of the attitudes of the students entering their classrooms. This calls for mutual cooperation among secondary and elementary teachers to develop an articulated science program.

THE UNITY OF SCIENCE

As teachers we have all faced the question, "What is science?" The term science covers many facts, natural laws, and a variety of subject matter. Yet it has a unity recognized by all.

The heart of all science is inquiry! In all areas of science, regardless of the kinds of objects or materials used, the scientist makes *his own* observations, asks *his own* questions, performs *his own* experiments, and draws *his own* conclusions. This approach remains the basic significant characteristic of all science, not the body of facts obtained. However, it is through such an approach that the accumulation of knowledge (facts) in each area of science is achieved.

THE NATURE OF INQUIRY

The term inquiry can be most succinctly defined as a search for information and understanding. This, of course, implies that the person (adult or child) conducting the search has a general notion of the problem he is attempting to solve. There are many instances in the history of science, however, where the scientist had no more than a general notion of what he was searching for and, as a result, all the data gathered were carefully evaluated before the specific problem to investigate was solved, or in many cases, even defined. Pasteur, for example, began his scientific career as a chemist and, as a result of attempting to solve the problem of beer and wine fermentation, was launched on an inquiry which led to the development of the new field of bacteriology. The nature of the processes of inquiry demands that situations be analyzed, investigations conducted, information evaluated, hypotheses synthesized and tested, generalizations formed and, ultimately, predictions made. Developing the ability to inquire demands that the learner have an active role in an investigation; he will not develop his powers of inquiry (the rational powers) if he assumes only a passive or listening role.

Of all man's possessions, the most valuable is the knowledge he possesses. But of all his knowledge, the most priceless and personal is that which he has discovered for himself.[4] The role of the processes of inquiry in elementary school science to furnish a framework which can be used to lead a child to discover information *for himself*. We must not expect that a child will discover anything new to science but what he does find will be new to him. Furthermore, the very nature of the processes of inquiry demands that if the learner is to discover facts he must make observations, perform experiments, interpret data, form and test hypotheses and draw conclusions. By participating in these processes the learner is having experiences which will develop his intellectual abilities (rational powers) and is accumulating information and understanding which are uniquely his. The factual information which he accumulates, however, is of secondary importance when learning by inquiry; the most important achievement is the development of an understanding of *how to inquire and make discoveries*. Inquiry, therefore, is the learning process in science because it is used by the learner to find out what it is he wishes to know. It is also an end product because by understanding how one problem is solved, the learner is in a position to better know how to solve the next problem. All of these kinds of experiences lead him to his most priceless and personal possessions–that knowledge which he has acquired for himself. Since a learner cannot acquire all the knowledge and understanding during his school years that he will need for life, *the schools must teach him how to*

[4] Jerome Bruner, *On Knowing*, (New York: Atheneum Publishers, 1965), p. 82.

continue to learn on his own after he leaves school. Providing educational experiences which will teach the pupil how to learn is the school's most important responsibility. Learning science through inquiry represents a learning experience which can be used in the classroom to help the school meet this important responsibility.

THE NATURE OF THE LEARNER

During this century psychologists have made extensive studies of the development of thought in children. In particular Piaget and the investigators who work with him at his research institute in Geneva have spent many years in trying to trace the gradual growth of ideas about numbers, quantity and space, and in studying the ways in which children's thinking changes as they grow older. Children do not think like adults until adolescence. The complex processes of thought are acquired gradually, developing from the extremely simple forms found in the young infant. What the psychologists have observed is of the greatest importance to teachers in planning the experiences they will offer to children. It is these experiences of making discoveries through their own actions and attempting to express what they have discovered which enable children to *think* science instead of merely carrying out operations mechanically and without real understanding. Moreover, familiarity with the characteristic growth of children's thinking helps a teacher to identify the stage which an individual child has reached. Many of the experiments and observations undertaken and analysed by the Geneva School have been repeated in this country and checked by alternative methods. Not all Piaget's findings have been confirmed but a considerable number have been verified and a general pattern of development seems to have been established.

Stages of Growth of Intellectual Development

The following stages of growth have been distinguished, though some writers number them differently.

I. Stages of Intellectual Development

A. Sensory motor	(0-2 years)	(Stages differ in way information is received and processed. Ages are flexible for stages.)
B. Preoperational	(2-7 years)	
C. Concrete operational	(7-11 years)	
D. Formal operational	(11+ years)	

II. Characteristics of Each Stage

A. Sensory-motor stage (0 - 2)
   1. Receives information primarily as series of unrelated perceptions and reacts overtly to the perception. ("sees"--reacts) leading to practical satisfaction.
   2. Processes in latter part of stage in "repeatable patterns of action!"

3. Problem-solving: crude trial and error.
4. Major accomplishment: permanence of object (image formation) trial and error.

B. Preoperational stage (2 - 7)
1. Forms a simple concept or category but has difficulty with subtle similarities.
2. Problem-solving: refined trial and error.
3. Karplus describes as perception bound.
4. Wohlwill describes as: "Lives In Alice In Wonderland World!"
5. Amounts of substances; the number of objects, length, etc., vary with arrangement or transformation. He does not conserve!
6. Why does he not conserve?
   a. Centers
   b. Does not equiliberate
   c. Irreversible
7. Egocentric
8. Can hold image in mind but cannot deal effectively with transformations of objects or groups.

C. Concrete operational stage (7 - 11)
1. Can follow properties of objects through transformations.
2. Can perform an operation on concrete objects or situations; i.e., can mentally carry out a series of related actions on objects with which he has had experience.
3. This allows the child to:
   a. Develop and deal with a hierarchy of concepts
   b. Deal effectively with concepts developed through concrete experiences
   c. Problem-solving: can mentally solve by reasoning from concrete situations.

D. Formal Operational stage (11+)
1. Logical operations can be carried out in the mind without the aid of concrete materials.
2. Can think about the consequences of his thinking
3. Can deal with abstract models
4. Can manipulate variables of experiences mentally

These stages are well marked but the ages differ among children. Their rate of development depends in part on innate ability but there is strong evidence that it is influenced considerably by the kind and range of exploratory and constructional activities that have been open to a child. The transition from one stage to the next is not sudden. A child will show on occasion during stage 1 some of the characteristic thinking of stage 2, and during stage 2 he will sometimes operate at the level of stage 1. Regression to an earlier way of thinking may take place at any age in the face of a completely novel situation or a very difficult problem.

It is evident that intellectual growth and the development of the structures with which the learner has to think are influenced by: maturation, experience, social transmission, and equilibration. For a more detailed study of the learner refer to the General Professional Bibliography.

THE BASIC PHILOSOPHY FOR THE SCIENCE PROGRAM

We as teachers subscribe to the overall goal of education which is to provide the individual with a means for improving himself and the society in which he lives.

Traditionally, science teaching has involved the teaching, memorizing and applying of so-called "scientific laws or facts." We feel that every effort should be made to break away from this traditional method at all levels. We believe that to develop an understanding of an ability to utilize the fundamental concept of science as inquiry, a teaching approach different from the one many teachers now use, must be employed. The inquiry approach to science teaching, we feel, is the logical and productive approach.

Science is a natural vehicle with which to develop a student's ability to think objectively. In order to accomplish this goal, however, the emphasis in science teaching must shift from the teaching of facts to the development of a student's ability to observe carefully, collect information, and draw logical inferences. In other words the student acquires *his* scientific information only through *his own* powers of observation and inductive inferences. *The process*, therefore, *of arriving at an item of scientific information becomes* more important than *the information obtained.* If such logical philosophy is adopted, the actual objects used in making critical observations and drawing inferences are not important. These objects can be buttons, rocks, plants, animals, or any convenient and available items.

The inquiry approach discussed above has a remarkably beneficial effect in increasing the interest of the student in science and in increasing his ability to think logically in other areas. Such an approach gives the student excellent opportunities to learn to express himself accurately and concisely. This ability has value in all the other disciplines.

The inquiry approach to science teaching necessitates that teachers adopt the attitude that science is an intellectual process. This attitude may not have been developed through the formal education in science which the teacher has experienced. It is important that procedures be developed within the framework of teacher education which will enable the prospective teacher to become involved with science as an intellectual process, not a body of laws and facts.

We recognize that elementary school children, as well as many elementary teachers, have not had experiences and opportunities to acquire the basic knowledge of scientific laws and facts with which to observe and interpret correctly all of the events involved in the learning situation created in the science classroom or laboratory. We also recognize that one cannot leave a class "wondering, with no basis for understanding what they have observed." However, this is where successful teaching occurs. The successful teacher takes advantage of the "wondering" and *guides* the student into finding (not gives) a satisfactory (and correct) explanation. It is the way of searching for laws and facts which is important and this, both teacher and students must accept and understand. *The student must seek to know and understand the "law and facts" as answers* to his questions and needs rather than be given them as information for which he may eventually have a use.

CURRENT TRENDS Interest in improved and more effective learning has created an awakening to a broader and more appealing science curriculum. Trends which have emerged during the past few years include the following:

1. Behavioral change is a basic consideration in curriculum planning.
2. Emphasis is being placed on understanding broad conceptual scheme and processes of science, rather than memorizing facts, thus reducing amount of course content.
3. An interdisciplinary approach with well-articulated science involvement (as opposed to testbook, one-discipline approach) is expanding.
4. The textbook-centered approach, emphasizing accumulation of knowledge, is being replaced by the laboratory-centered approach which emphasizes problem solving and learning skills.
5. Multi-media materials are utilized to meet stated educational objectives.
6. Individual, independent, and small group instruction comprises a greater portion of the teaching day. This presupposes that individuals differ in learning rates and learning styles and that students will be motivated primarily by the materials or processes of instruction themselves.
7. Short courses (modules) are built around conceptual schemes.
8. The classroom is being extended to make more effective use of the outdoors and the special interests and skills of parents and other people in the community.
9. Flexible scheduling is providing for extended use of materials and facilities by greater numbers of students.

10. Differentiated staffing is facilitating more effective use of teachers' special competencies.
11. Emphasis is being placed on science experiences to develop basic scientific literacy for all students rather than merely preparation for higher education or college.
12. Humanization of the curriculum with emphasis on openness, trust, and the needs and concerns of individual children.

PURPOSES OF SCIENCE EDUCATION

The general purpose of the elementary school is to develop the rational powers of the mind, that is, the ability to think.[5] Science experiences make their unique contribution to the development of this ability to think by leading children to develop:

The ability and *confidence* to inquire,

understandings of matter, life, energy, and their interactions.

The accomplishment of these objectives will encourage the transfer of learning from one context to another and help children become thinking, creative citizens.

The purposes of science education which we, the junior and senior high school teachers of Oklahoma, propose fall into two categories:

1. The Achieving of Scientific Literacy.

In the NSTA Position Statement on School Science Education for the 70's the following characteristics were listed to describe the scientifically literate person. These characteristics should also be considered when looking at student behavior in science:

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[5] *The Central Purpose of American Education, Educational Policies Commission, NEA, 1961. The rational powers are recalling, imagining, classifying, generalizing, deducing, inferring, evaluating, synthesizing, analyzing, and comparing.*

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- "uses science concepts, process skills, and values in making everyday decisions as he interacts with other people and with his environment
- understands that scientific knowledge depends upon the inquiry process and upon conceptual theories
- distinguishes between scientific evidence and personal opinion
- identifies the relationship between facts and theory
- recognizes the limitations as well as the usefulness of science and technology in advancing human welfare
- understands the interrelationships between science technology and other facets of society, including social and economic development
- recognizes the human origin of science and understands that scientific knowledge is tentative, subject to change as evidence accumulates
- has sufficient knowledge and experience so that he can appreciate the scientific work being carried out by others
- has a richer and more exciting view of the world as a result of his science education
- has adopted values similar to those that underlie science so that he can use and enjoy science for its intellectual stimulation, its elegance of explanation, and is excitement of inquiry
- continues to inquire and increase his scientific knowledge through his life"

2. To Foster Intellectual Development.

Science, taught through inquiry, can contribute to the intellectual development of the student in two very imprortant ways. First, it can provide the student with the opportunity to use his rational powers,[6] (recalling, imagining, classifying, generalizing, comparing, evaluating, analyzing, synthesizing, deducing, and inferring), which are essential to logical thinking. It is only through use of the rational powers that they can develop and that a very important goal of education, the ability to use logical thought processes, can be accomplished.

The second way in which science taught through inquiry can contribute to the intellectual development of the student is in the area of cognitive development as described by the Swiss psychologist, Jean Piaget.

His data have led him to propose that when a child enters school he is perception bound, or at the preconceptual level of thinking. The students cannot think about their own thinking. Around age seven, the student begins to lose his rigidity of thinking and can do mental operations with concrete objects. The student is in transition from preconceptual to the conceptual level of thinking. This stage is called the concrete operational level.

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[6] *The Central Purpose of American Education. Educational Policies Commission. NEA. 1961. The rational powers are recalling, imagining, classifying, generalizing, deducing, inferring, evaluating, synthesizing, analyzing, and comparing.*

The concrete operational learner can use simple logic in the collection, organization and interpretation of information. The concrete operational learner has great difficulty in structuring information into abstract models, such as the atom, for the purpose of information storage or retrieval. He finds it practically (if not actually) impossible to reason from one abstract model to another. He has great trouble for example in relating atomic structure to energy of reaction between atoms. This inability to deal with the hypothetical or highly abstract models places severe limitations on the learner not only in science but in other areas as well.

The last stage of the intellectual development process is called formal operations. Around age 12, the student begins to enter a stage when he is able to think in the abstract. The student can think about the consequences of his thinking. He begins to verbally express himself with statements that "if" this happens "then" caused it or is a result.

In order to develop scientific literacy, science education must ultimately help the learners achieve a conceptual knowledge of their environment. In addition, and equally if not more important, science education must promote the spirit of rational inquiry that is the spirit of science. The values associated with the spirit of science are: [7]

1. Longing to know and understand.
2. Questioning of all things.
3. Search for data and their meaning.
4. Demand for verification.
5. Respect for logic.
6. Consideration of premises.
7. Consideration of consequences.

One of our colleagues wrote, "Individual involvement is essential in the learning of scientific concepts." One can readily see that individual involvement, (collecting, organizing, and interpreting information) is also essential to the development of the spirit of science and the ability to inquire rationally.

THE TEACHING-LEARNING PROCESS

A question often asked is, "How are inquiry situations developed in the classroom?" The following discussion will provide assistance in answering that question.

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[7] *Educational Policies Commission, Education and the Spirit of Science, Washington, D.C., 1966, p. 15.*

HOW DOES A TEACHER EMPLOY INQUIRY TEACHING METHODS IN THE CLASSROOM?

There are two roles in any classroom--the teacher and the learner. In an inquiry-centered classroom each of these roles must have an active participant because the actions of one will be greatly influenced by the actions of the other. In the discussion which follows the assumption is made that learners are free to investigate.

Inquiry-Centered Teaching And Learning Responsibilities

TEACHER	LEARNER
1. If the learners do not have a topic to investigate, the first responsibility of the teacher is to provide a topic to investigate.	1. The learner does the investigation; in other words he designs the procedures necessary for the investigation and collects information.
2. The teacher asks the learners for the information collected from the investigation.	2. The young investigators describe what has been found.
3. This teacher responsibility cannot be stressed too strongly: the teacher accepts the findings which the learner describes. In addition, the teacher urges the learner to search for a pattern in the information collected. Usually the learners will need to be asked questions to keep the search going. The teacher may need to provide clues.	3. The learner searches the information for some type of a pattern and, usually under the guidance of the teacher, finds a pattern. Do not expect all the learners to find the same patterns; if several interpretations of the information are made, and if these interpretations are valid, the inquiry process is being especially productive.
4. The teacher next questions about the relationship of the pattern found to the topic being investigated. Is the pattern relevant to the topic or has some new idea been uncovered? Perhaps the teacher will need to invent[8] a new concept.	4. The learner is now led to generalize from the interpretation he has made of the collected information. He is now in the position to form a new concept for himself or the teacher can now invent the concept; that invention, however, must be based upon the information collected.

[8] *For a complete discussion of concept invention, see J. Myron Atkin and Robert Karplus, "Discovery or Invention?" The Science Teacher, September, 1962, P. 51*

5. Questions can now be raised about the relationship of the new concept just formed to concepts which were based upon previous investigations. The inquiry-centered teacher will raise the questions and allow the learners to discover such relationships by exchanging ideas, not by telling them what that relationship (if any) is. These questions should always be asked and not only when a relationship exists.	5. The learners are now, by using the process of inquiry, accomplishing something that every teacher wants his students to accomplish, i.e., they are broadening their understanding of a scientific principle. This broadened understanding, however, is possible because the learners have been involved in developing the information which led to the invention of the concept. They are not "broadening" their understanding by simply being told that this new concept applies in many different situations.
6. For a teacher who truly believes in inquiry and who also believes that any new idea must be subjected to the arena of disproof, this phase of inquiry teaching is the most stimulating and pedagogically worthwhile. The teacher raises questions about value, meaning, and/or validity of the concept which has been developed. The teacher must keep firmly in mind that he must accept the pro and con student arguments relative to the concept's value, meaning and/or validity.	6. The learners now must defend not only the concept which has been developed but also their procedures and thinking processes which were used in arriving at the concept. They are having to apply the inquiry process to the results of an inquiry process. As understanding of an idea deepens through inquiry, one is truly learning how to learn as he clinically inspects and evaluates the results of his own thinking. The learners are now in the position of suggesting other investigations which will either confirm or deny the exactness of the concept. If they are in need of assistance, the teacher has one additional responsibility.
7. The teacher may need to suggest additional investigations to test the concept's validity. [9]	

[9] *Renner, John W., "Using Inquiry in the Science Classroom," Educators Guide to Progress Service, Randolph, Wisconsin, 1969, p. XX-XXII.*

THE LABORATORY AS A LEARNING ENVIRONMENT

For the inquiry approach to be most successful, the classroom should be organized in such a way that it becomes a laboratory in which pupils can have actual experiences with natural objects and phenomena. Each child's discoveries are his own and are a direct result of his own actions and manipulations. Thus, he experiences science firsthand.

The ideal classroom for elementary science is one which has all the necessary materials for the students to conduct their investigations. This would mean an abundance of materials for students' use and these materials should be supported by reference books and other materials. If the children in this kind of classroom are allowed and encouraged to carry on their own organized, science-oriented activities, one can expect to kindle real interest for each child in some way at some time.

In an article dated July 7, 1962, in the *Saturday Review of Literature*, Dr. Warren Weaver, Vice President of the Sloan Foundation in New York said:

> "It seems to me absolutely essential that the student do something more than listen to lectures, look at demonstration experiments, study a textbook, and recite lessons. All these things are good, but they are not enough. In addition the students simply must do something on their own, with their own minds and with their own hands. They must have a 'scientific experience' even if it is so simple as swinging a bunch of keys hanging on a string and timing this pendulum with their pulse."

Any science course that the student has without the benefit of concurrent laboratory experiences is not science but is simply *about science*.

The experiences that the students have in the laboratory should be inquiry oriented. They should aid development of the rational powers. The trend today is toward open-ended activities. This type activity is not designed to verify but instead to lead the student to new avenues of investigation. The student not only gains understanding of natural laws, i.e., F=MA, V=IR, etc., but sees these natural laws not as final results but simply bits of data which will lead to further inquiry and further science competencies.

Two statements made regularly by students in a science laboratory should bring tears to the eyes of the modern science teacher. They are:

1. "I've done the lab."
2. "Did this do what it was supposed to?"

The first statement is usually heard at the end of a laboratory period and the translation means "I have followed the lab manual step by step. All the blanks are filled in and the percent of error is within the-5% which you will accept. I would like to turn in my paper now. . . and take a nap." The

student sees the laboratory not as a place to explore but rather as an exercise room in which he must do a prescribed number of "science pushups." He never realizes that an investigation can be judged by the number of questions uncovered as well as by the number answered. This student never experiences the desire to continue after the last blank is filled in.

The second statement is often heard during the last half of the laboratory period. Translated it means, "Here is what I have in the blanks. Is it acceptable to you?" This student really doesn't think that a pendulum bob, or a strip of litmus paper, or a pickled perch can do other than what it is "supposed" to do. The learner simply wants to know, before committing himself, if the teacher will accept the findings.

Either statement should tell the alert science teacher that something is wrong with the course or the students. Budding young scientists as well as seasoned old veterans must realize that the "lab" is never done. Any experiment worth its salt will open new avenues of investigation. The learner should know that instruments may lack percision, measurements may be in error, and observations biased, but nonetheless he continues. Conclusions must be completed, but the vehicle of inquiry which carried this experiment, like ole man river just keeps rolling along.

One of the best examples of the "open-ended experiment is one which has been christened the "black box" experiment. This particular activity is excellent for use early in the school year. Each student is given a sealed box containing some object (pill boxes obtained from the drug store are excellent). The students are asked to first obtain as much information as possible about the object without opening or damaging the box. The students can shake the box and gain information about the object's size, hardness, shape, mass, and possible texture. After a sufficient time, the student is asked to "describe and/or name the object in the box." No time deadline is given for this assignment and no student may damage or open the box. This experiment may last a week or a month or several months, but almost all students will give a very good description of their object and a very high percentage of the students will correctly identify the object. The significance of this experiment, aside from the use of rational powers, is that all systems in science were originally or are still black boxes. A modern example is the atom; we must describe the atom without "seeing" it. Other examples are: gravity, magnetism, electricity, and even life. Currently all of the recommended programs make extensive use of the "open-ended" experiments.

SAFETY IN THE LAB

*The Science Teacher, January, 1977, Volume 44, No. 1; Compliments of Codevintec Pacific, Inc., 6263 Variel Ave., Woodland Hills, CA 91364

SAFETY IN THE LAB

You, the teacher are primarily responsible for the safety of the learners and yourself in the laboratory, classroom and field excursions. You must be safety minded at all times. You must set the example for students by following the safety rules such as wearing eye protective devices. Also, when visitors enter the lab where experiments are in progress, provide them a pair of safety glasses.

The School Laws of Oklahoma, Section 356 states. "Safety Goggles--School Board to Provide for certain personnel. The school board of each school district in Oklahoma shall provide safety goggles as approved by the National Safety Council for all personnel using materials and machines that may damage the vision of such personnel because of flying particles, intense light, severe heat or other harmful effects. (70-24-117) Section 357 states: "Respirators--School Board to Provide for Certain Teachers and Students. The school board of each school district in Oklahoma shall provide respirators where needed in the opinion of the State Health Department as approved by the National Safety Council in sufficient numbers to protect teachers and students in industrial arts, vocational training, technical training and chemistry classes using or handling toxic materials or other substances which may cause damage to the respiratory system and shall further direct that such respirators be maintained in satisfactory working condition and are located within easy access wherever such materials or substances are used or stored. (70-24-118) These two laws are meant for your protection as well as the learners.

Other factors you should consider while teaching are: (a) the pitfalls and cautions listed in the textbook or lab workbook, (b) the cautions you are knowledgeable about, and (c) the factor of time and the fact that you as a teacher will be exposed to minimal or marginal safety conditions possibly six hours a day.

Consider the following concerns while you are teaching:

1. Rules for good housekeeping are established.
2. All materials are labeled correctly and stored safely.
3. All materials are easily accessible.
4. Provide learners a list of pitfalls and cautions and when necessary demonstrate safety practices, i.e., cutting glass, lighting a match, handling acids and bases, etc.
5. Learners should be able to manipulate tools and know how they function.
6. Provide adequate disposal for broken glass, spilled liquids, dissected animal materials, cultures, toxic chemicals, etc.
7. Provide adequate care and nutrition for plants and animals.

8. Consider your actions as to the possibility that they might promote trauma, undesirable psychological or physiological effects upon the learner.
9. Do you have a checklist of safety practices that you can provide the learner?

The Guides for the Indiana School Science Program suggest the following concerning Safety in Science:

Since science requires the learner to play an active role in the learning process, the student needs a workroom where he/she can control the conditions of observations and investigate a variety of problems. In this workroom the student will use a wide variety of manipulative equipment, living organisms, glassware, chemicals, and many types of scientific apparatus. All of these may be potentially dangerous if handled improperly; thus it is essential that safety practices must be a part of science learning.

All students must develop sensible attitudes about safety precautions in sciencing. Attitudes determine behavior and cannot be taught as abstraction but must be built from actual learning experiences. Simple explanations of what not to do must be reinforced with understandable reasons. Safety attitudes cannot be left to chance. The school must guide students toward those meanings and behaviors which produce safety for the individual and society. The school must accept the responsibility for a safety program beyond the traditional campaign aimed at pedestrian, hallway, and driver safety.

The school should develop and implement a comprehensive safety program as an integral part of the science program. This program should be implemented and supported by an administrative policy statement. The program should include:

1. A continuous preventive educational program for each level and area of science, K-12.
2. Procedures and instructions concerning potential hazards common to science classes. These hazards include caustic and explosive material, liquids and solids at extreme temperatures toxic fumes, poisons, sharp objects, electrical circuits, radiation sources, etc.
3. Signs identifying hazards and reminding students of safe practices.
4. First aid kits with written procedures for first aid treatment for every teacher.
5. Programs for supervision and monitoring students for compliance with safety regulations.
6. Well kept records of school accidents to identify specific hazard areas and improve precautionary practices.
7. Rooms, furniture, and equipment designed to include provisions for safety in science rooms. [10]

[10] *Indiana School Science Program, K-12. State of Indiana, Department of Public Instruction, 1971 p. 125.*

CHARACTERISTICS OF A GOOD SCIENCE PROGRAM The checklist is intended to provide the science teacher and the administrator an instrument which will enable him/her an instrument to evaluate the science program of the school. From the results of this in-house evaluation, appropriate actions to remedy any deficiencies should be planned and carried out.

THE SCIENCE PROGRAM	IDENTIFY CONSTRAINTS AT APPROPRIATE LEVEL		
	ELEMENTARY SCHOOL	MIDDLE SCHOOL	SENIOR HIGH SCHOOL
1. To what degree is there a sequential K-12 science program which provides growth and development? We have been thinking about it. We follow our basal text series but don't know what other grade levels are doing. We determine the level at which children can achieve successfully and provide the necessary opportunities for continued growth and development of a positive self-concept.			
2. Does the program provide opportunities for student exploration and discovery? We only talk about this. We have only teacher or individual demonstrations. Individual and small group investigations are frequent.			
3. Does the program provide the development of varying student abilities and skills? We use only a basal program providing identical learning on an identical schedule. We supplement the textbook with some additional materials. We use a wide range of multi-level materials and enrichment activities such as guest speakers, manipulative materials, audiovisuals.			

THE SCIENCE PROGRAM	IDENTIFY CONSTRAINTS AT APPROPRIATE LEVEL. ELEMENTARY SCHOOL	MIDDLE SCHOOL	SENIOR HIGH SCHOOL
4. To what extent does the program utilize community resources? We limit our program to the immediate classroom. We allow children to examine the outdoors during fire drills and P.E. We take meaningful field trips and frequently call upon local resource persons.			
5. To what degree are the present facilities and equipment being used? No science interest centers are evident; science equipment is inaccessible. Most teachers are using some equipment. The others are learning. Equipment is available and in constant use by students.			
6. Is there a media center in the school which includes current science materials? Some science books and film strips are available. Books, periodicals, and various audio-visual materials are available on all levels. Students constantly use a variety of media in and out of the media center.			
7. Does the school have a procedure for original purchases and re-stocking of consumable science supplies? Never thought of doing it. We have no inventory. Only when requested by a teacher. Teachers and children bring most of the materials from home.			

THE SCIENCE PROGRAM	IDENTIFY CONSTRAINTS AT APPROPRIATE LEVEL		
	ELEMENTARY SCHOOL	MIDDLE SCHOOL	SENIOR HIGH SCHOOL
Maintain inventory. Science program included in annual budget. Lead teacher responsible for inventory and purchase request.			
8. Is science a regular part of the school program throughout the entire school year? We teach science one semester, alternating with health or social studies. We teach science all year-when children brings things in and when it relates to other subjects. We set aside time each day for science activities and provide additional time for work on special project interrelated with other subjects.			
9. Is there a science advisory committee in the school district? No. Each school sets up its own curricular program Teachers work together on book adoption committees when needed. We have a district advisory committee which is composed of a lead science teacher from each school. This committee provides articulation within the K-12 program, examines new programs, and works toward continued implementation of better science curricula.			

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THE SCIENCE PROGRAM	IDENTIFY CONSTRAINTS AT APPROPRIATE LEVEL		
	ELEMENTARY SCHOOL	MIDDLE SCHOOL	SENIOR HIGH SCHOOL
10. Does the school have a science chairman? Each teacher plans his/her own science program Teachers of each grade level meet periodically to discuss the science program. The school has a science chairman who meets periodically with the lead teachers of each grade level to review the program, plan for changes, inventory, and order and store equipment.			
11. Is central storage provided? Teachers bring materials from home. A few materials are in the library, office, and any available closets. A closet is designated for storage of equipment which must be shared. A central storage area is provided. One person is in charge and responsible for maintenance, replacement and checkouts.			

EVALUATION WITHOUT TESTS [11]

Planning Ways to Evaluate Progress

The Nineteenth - Century German chemist Justus Von Liebig described the beginning of a new field of science as " nothing more than a series of observations and experiments which had no obvious connection with one another."

Professor von Liebig was also describing how science expands, progresses, and forces man to use and develop his intellectual capabilities. He was clearly stating that two of the activities which comprise science are ***observing*** and ***experimenting***. In additon to these, ***measurement***, ***data interpretation***, and ***prediction*** are also part of the fabric of science.

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[11] *Science/Junior High School Edition, Advance Planning Issue, 1968-1969 Croft Educational Services, New London, Connecticut.*

These five basic activities of science are all behavior oriented. If, then, a learner is provided experiences with these five activities and is evaluated in terms of how well he functions with them, teachers will have clearly demonstrated that their primary objective in teaching science is changing the learner's behavior. Behavioral change is a primary purpose of all educational experience.

Let's Agree

How does one evaluate how well a student has learned to observe, measure, experiment, interpret, and predict? Before answering that question, there are three points about teaching, learning, and evaluating which must be agreed upon. They are:

1. *Teaching is not telling*. Exclusive use of the lecture represents ineffective teaching.
2. *Memorization is not learning*. Asking students to memorize material is probably not developing their ability to learn.
3. *Being able to repeat is not evidence of understanding*. Recall test items probably measure very little behavioral change.

Since "tell'em-show'em-ask'em" procedures do not make use of the five basic activities of science in teaching, such procedures will not allow you to determine if the activities have changed the learner's behavior. Therefore, what follows assumes that science is taught as investigation, not as fact-accumulative process.

Now let's look briefly at the five activities mentioned above to see the general approach to evaluation.

What is observation? It can be defined as looking at an event, object, or situation and being able to describe and understand what is seen. In studying science, the opportunity to develop this ability is provided in many ways. An adequate statement of the problem being investigated reflects that observations on prior experiments or on the work of others have been carefully made. Recording the results of an experiment (and not what the learner thought the results should be) is evidence of careful observation. Direct experiences in observing must be provided the learner, but the teacher must evaluate *indirectly* if the student has learned how to observe.

The same situation exists with the other four basic activities.

What is being evaluated in experimentation is whether or not a learner is willing to put together all the information he has and take a step into the unknown. How do you evaluate this type of behavioral change? A paper and pencil test, essay or objective, will not do it because there the learner need only talk about experimentation; he need not demonstrate his willingness to behave in a specific manner. What the learner *does* when

meeting an experiment determines if the experiences provided have changed his behavior.

Specific Criteria

The following five questions can be used as criteria to determine if the five activities of science have changed student behavior.

1. *Does the student state the problem being investigated clearly enough to enable him to devise an experiment for it?*

If the student can imagine, design, and conduct an experiment from his statement of the problem, he has made careful observations and interpretations of other experiments or information from other sources.

2. *Does the student record all the data from the investigation and not just what he thinks the data should be?*

If you can say yes to this question, you can be sure that the student is learning to observe and measure, and that these activities are affecting his behavior.

3. *In interpreting the data, does the student state only those interpretations which the data will support?*

Applying this question honestly, objectively, and regularly will give information about how the interpretation experiences you are providing are changing behavior. Not infrequently, what a student interprets from an experiment depends on what he believes the teacher will accept.

4. *Were the conclusions the student drew based upon actual findings and not upon his preconceived notion of what should be found?*

Here, of course you are evaluating how observation, measurement, experimental results, and interpretation have influenced the learner.

5. *Does the student approach the next investigation using the results of the last one?*

In addition to being evidence of a true behavior change, an affirmative answer here is evidence that the learner has internalized the meaning of prediction. He has evidenced faith in his findings by being willing to base future actions upon them.

Practical Suggestions

How do you use the foregoing criteria? How much of a student's grade should be based on them? These questions deserve practical answers.

You need to keep records, so prepare a sheet (use the ditto machine) for each student which lists the five questions, and put the sheets together in a looseleaf notebook. Record evidences on each student as they occur. Some weeks you may have several items to enter, other weeks nothing will appear. Remember you are looking for evidences of true behavioral change or lack of it.

Is this procedure subjective? Certainly. So are other evaluation procedures. Any pencil-and-paper test is based on the teacher's subjective opinion on which questions to ask. In this new situation you must rely on your day-by-day experiences with students for information on which to make judgements.

Does this procedure require additional work? Probably. But keeping the records suggested is simply keeping an expanded gradebook. When the time to prepare the final grades arrives, the information you have on each student will make the effort worthwhile.

How much weight should your records on behavioral progress have in computing the student's final grade? Ideally, this information should determine that grade. However, in most communities, the public is not ready for such a move - parents expect schools to use fact-centered examinations and teachers to use numbers (not logic) in determining final grades.

You will note that the five evaluative criteria suggested must be applied during investigations. Since the laboratory is normally an integral part of science, fifty per cent of the final grade coming from the five criteria seems reasonable. Be sure to inform the students of the criteria you are going to use in determining this significant portion of their grades.

In Summary

The evaluation of student progress in science can be done in many ways beside paper-and-pencil test. To utilize other methods of evaluation, the teacher must be sure of his purpose at the beginning of the year and select that content and those teaching procedures which will allow the learners to work toward the achievement of those purposes. The five basic activities of science have been suggested as constituting behavioral objectives that can be used as the basis for student evaluation.

As you teach toward changing student behavior through the activities of science, you will need to examine your teaching approach.

The following questions are referred to as checkpoints by the author.

Do you listen to students?

Listen to what students have to say about an investigation or problem and utilize their contributions in carrying forward the classroom activities. This does more than establish rapport; it tells the students that they, as well

as you, have a responsibility in carrying out the learning activities. A teacher who listens tells the learners that what they have to say is a valuable part of the investigation being conducted. Be a good listener.

Do you accept the results which the students get in an investigation?

Too many times teachers will accept only experimental results that constitute the "right" answers. When a learner has honestly done an experiment, you have the responsibility to accept his/her results.

What do you do if the results are unacceptable to science? Suggest other investigations which represent different ways of solving the same problem. The second investigation will probably produce results contradictory to the first. Now the student must decide which set of results to accept, and he/she will see that one of the investigations (perhaps both) must be done again. If you reject the first set of results, the learner will put future investigative efforts into guessing what results you will accept. Be an acceptor.

Do you ask questions which focus the student's attention on specific points in the investigation?

Ask many questions to find out what the students are thinking; few of the "can-you-guess-what-I'm-thinking" type. When the learner gives you an honest reply, accept it; and if that response is one which could lead the learner astray, ask another question which will demand and/or allow him/her to refocus attention. *Ask Questions.*

Are you a guide for students during an investigation?

Ask questions, provide cues to those frustrated and/or on dead center, recommend other investigations to perform, suggest alternate ways of thinking about a problem, challenge results, and provide materials needed. *Be a guide, but do not lead by the hand.*

For a year's work, are you more concerned with the type and quality of investigations than with the number completed?

The "we-must-finish-the-book" attitude has no place in a classroom which is concerned with changing student behavior through utilizing the five basic experiences of science (sic; observation, experimentation, measurements, data interpretation, and prediction).

CHAPTER II

DEVELOPING A PROGRAM IN SCIENCE EDUCATION

A PLAN TO MEET LEARNER NEEDS—A SYSTEM ANALYSIS PROCESS

The primary purpose of a system analysis process is to insure that each boy and girl has the opportunity to receive an instructional program that fits his or her particular need. The following outline is a planned sequential process identifying the steps necessary to maximize the individuals learning potential. The plan must reflect the process of inquiry in its implementation. Where applicable instructional goals should be stated that accomplish the content offering you desire.

System Analysis Process

Components	Student (Example)	Instructional (Example)
a. Needs assessment	a. Leadership	a.
b. Priorities	b. Relate to all needs and choose those that need emphasizing	b.
c. Goals	c. The students should become familiar with qualities that exemplify good leadership	c. The students should become familiar with the role of classification in science
d. Objectives	d. Presented with a laboratory activity, the student will organize a team of three students to complete an assigned task	d. Presented with ten pictures of animals, or ten animal samples, student will: (1) identify characteristics of each animal, (2) place the animals into groups according to the characteristics the student identified, and (3) describe his own system for classification
e. Identification of constraints	e. Possibly the lack of a good model, you, may have to invent the model	e. Possibly not being able to find 10 pictures or 10 animals samples

f.	Generate alternate programs	f.	Alternative--assign tasks	f.	Alternative--choose plant leaves or common objects from the home
g.	Analysis and selection of an alternative	g.	Selection--having assigned tasks will the student perceive the transfer of leadership from you, the teacher to him/her	g.	Selection--will the alternative accomplish the same objective
h.	Activities	h.	Activity--use any lab activity, preferably one containing few variables and little hardware.	h.	Activities--investigation using photographs, pictures from magazines, or use samples from animal collection
i.	Implementation	i.	Introduce a lab activity and instruct the students to form groups of four. Each group is to choose the role each member is to assume in order to accomplish the investigation	i.	Introduce lesson to students, give them materials, promote investigation, and have class discussion
j.	Evaluation (recycle to needs)	j.	Were students eager to select roles? Was the lab activity accomplished?	j.	Try the same lesson using an alternative set of pictures, do not provide the guidance as before, evaluate student(s) on ability to duplicate content and process information as before, check verbal response, and check written responses.

Definition of Terms

Needs Assessment: A specific plan adopted by a local district to determine learner needs. The needs assessment provides a basis from which

priorities can be established as to what should be done to improve the instructional program.

Goal: A broad statement of purpose to be achieved to which the educational system will contribute by attaining related objectives.

Objectives: A statement of verifiable accomplishment which will advance the system toward its goal or goals. (What, when, how well or to what extent?)

Activities: Educational procedures designed to accomplish the specific objective which has been established for a specific program.

Evaluating: It is the process of assessing the attainment of objectives and the worth of programs.

The process illustrated is usually referred to as the system approach to planning. The system approach is merely one technique of technology to help insure good planning. This approach is helpful to define, identify, or isolate problems; and will lead to feasible strategies to bring about solutions to the problems. Notice that both include provision for continuous feedback, or order that modifications be made as necessary throughout the process.

It is important that the local action group explore several alternatives in order to be better prepared to make knowledgeable decisions relating to the adoption and implementation of their science program. In studying some of the experimental programs listed in this guide, a local group will need to clarify local objectives concerning science education and select and implement those materials which most nearly meet their particular objectives. They must decide either to accept a nationally developed program as it is, or develop the materials into a sequential articulated program designed specifically for the local situation. Progress has been real and significatnt at the instructional level in curriculum development. A relationship must be established among these efforts; gaps must be identified and closed, and fragmentation avoided.

A local action group can help to accomplish this by considering such problems as sequence and content of courses, grade placement, program for learner of varying levels of ability, different teaching styles, and relationships between science and other subject areas. As stated earlier, there is an increasing need to adjust nationally developed projects to fill local needs, and to develop a local K-12 science program based on basic principles and concepts organized into a sequential, well articulated, format.

The Role of The Teacher

We, the classroom teachers more than anyone else, realize that we are the key to the success of any program. Realizing this, we must continually experiment with new material and approaches and desire to do so. We should innovate and modify materials to fit our own teaching situation. We should seek in-service training sessions that stress inquiry, concepts, philosophy and rationale of the new science programs; and we want to participate in discussion groups with others engaged in similar experimentation.

We must maintain the spirit and approach of inquiry, the spirit of discovery, and above all provide for student involvement. A committment to developing the student's ability to inquire will force the teacher to get out of the way in order to give students room to explore ideas. Then, we must remember that the "finish-the-book" attitude has no place in a classroom concerned with developing a student's ability to inquire.

We, the classroom teachers, must create a classroom environment conducive to inquiry learning. The materials we provide plus our attitude toward the materials is a central force in shaping the classroom environment. Teachers who accept all honest replies and leave the decision to reject an idea or theory to the students will aid in establishing the proper environment. It will be a place where students can express ideas and try them out on each other, without fear of failure or embarrassement.

As stated earlier, the teacher must also assume a new role in the laboratory, one of "director of research." Students are viewed as the primary investigators, and we, the teachers, are there only to help, challenge, and oversee. We believe the primary responsibility of the teacher is to ask leading questions that require students to exert their own initiative to solve problems.

The Role of The Administrator

The administrator may be the superintendent, the principal, or the science supervisor, depending on the school system. In any case, the administrator must be the curriculum leader for effective change and must accept this responsibility from the start. The principals must not vacate their leadership role with the rationale that they aren't a science major, but must involve themselves during all the phases of the action program for change. A vital function of the administrator is to ask "searching" questions that call for reappraisal of the present program. They may do this in many ways: (1) use of the faculty meetings as a form of large-group instruction in which films, consultants, and other presentations provide teachers with information not readily accessible elsewhere, (2) review find-in of the latest North Central Evaluation on science programs, (3) organize faculty discussion groups to consider educational objectives of the school in relation to what they are doing in their classroom, (4) provide materials on educational innovations and encourage staff to make use of these

materials, (5) provide an opportunity for members of the staff to observe science programs in other schools and school systems, (6) encourage attendance at professional meetings, both local and national, by providing financial assistance and released time.

The science program in a school is largely the reflection of what the administrator believes, encourages or neglects. To obtain desired goals, the administrator must create and maintain a favorable climate for teaching and learning. The administrator who permits curriculum to be governed by convenience or expedience defeats the goals of a good curriculum. Policies and procedures can do much to enhance the learning that goes on in every classroom. A teacher in the classroom may innovate, but the administrator's reaction will limit the effectiveness if he/she opposes change. Administrators may stimulate the development of a quality science program by the changes he/she makes in scheduling, facilities, evaluation, and other instructional matters.

WE, THE SECONDARY SCHOOL SCIENCE TEACHERS OF OKLAHOMA, CANNOT OVER EMPHASIZE THE IMPORTANCE OF ADMINISTRATORS IN PROVIDING THE PSYCHOLOGICAL, PROFESSIONAL AND MONETARY SUPPORT SO NECESSARY IN UP-GRADING AND IMPROVING A SCIENCE PROGRAM.

Effective open lines of communication involving teachers, supervisors, and the public must be established and used by the administrator to insure a continuous study and revision of the science program.

Balance in the school curriculum must be maintained by the administrator to ensure that science is not over or under emphasized but *forms an integral part of the students total educational experiences.*

Above all, the school administrator must play the role of a facilitator, one who makes it possible for every teacher to achieve the goals for which the curriculum is designed.

The Role of the Science Consultant

Science consultants from within and from without the school should be contacted to aid the local action group. Science educators from the State Department of Education, universities and colleges may be contacted to secure consultive help. Consultants, if they are to be effective will work with administrators and teachers in determining means that provide for school needs as these needs are identified by the local school district and community.

A consultant does not dictate the approach nor the curriculum, but works closely with interested professional personnel to develop a program that is current and above all, meets the need of the local school district. Consultants may provide services within the framework of conferences,

workshops, in-service institutes and classroom visitations, they can provide current materiai on science curriculum development, counsel on the accuracy of curriculum materials, conduct demonstration inquiry teaching, and present the latest research findings on learning and evaluation, etc. The consultant's role is that of a co-worker in curriculum planning and in-service education.

Consultant service, to be of value, must be available over a long period of time in order to provide for follow-up and provide for adequate discussions on problems that develop.

THE LOCALLY DEVELOPED CURRICULUM MODEL #1

"Does a school system have to implement a commercially published science curriculum in order to have an inquiry science program?"

This question, which has been frequently asked by educators, should be answered with an emphatic "No." The commercial curricula materials are not absolutely necessarily a solid inquiry science program. The model presented in this section presents an alternate choice to those schools which do not wish to implement one of the existing commercial curricula.

Once the decision has been made that a locally designed curriculum is the logical approach to pursue, the local educators and consultants must decide what is to be included in the program. Of course, there is no question regarding the inclusion of those attributes which are basic to the science philosophy as presented in Chapter One. An inquiry oriented curriculum must promote those attributes which are listed below.

(1) The curriculum must be laboratory centered, that is, the learner must be engaged in experiencing the processes of science. These experiences must include the same operational processes in which the scientist is engaged. A partial compilation of these processes would include observing, classifying, measuring, experimenting, interpreting, and predicting. Thus, the learner is a scientist in this approach.
(2) The curriculum must, through the activities, reflect an understanding of the child's psychological development as presented through the theories of Jean Piaget.[1]
(3) The curriculum must aim toward the rational development of the learner based on the NEA document, *The Central Purpose of American Education*.[2]

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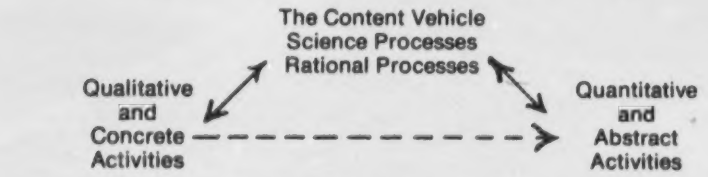
[1] *Jean Piaget, Psychology of Intelligence (Patterson, NJ: Littlefield, Adams and Company, 1963), p. 123.*

[2] *The Central Purpose of American Education, (Washington, D.C.: Educational Policies Commission, NEA, 1961.)*

An overview of the science curriculum based on these attributes can be illustrated with the following diagram:



The psychological flow of the curricular activity must progress from a qualitative, concrete type toward a quantitative, abstract type which coincides with the intellectual development of the learner. Woven into this progression are experiences which require the learner's operational utilization of both rational and science processes. Local curriculum developers must select the science content area which will permit the incorporation and developmental attainment of these curricular attributes.

Another decision which the educator must make relates to the approach to the lesson activity. One approach is based on related, day to day activity. This might be described as the pursual of inquiry simply for the sake of inquiry. There is no attempt to correlate individual activities.

A second approach is more complex with regard to day to day coordination. This type perhaps can be described as being more of an investigatory nature since the investigation of a single topic area might be pursued over a period of days.

K-12 Curiculum Model

	Level I					Level II			Level III			
Grades	1	2	3	4	5	6	7	8	9	10	11	12
Stage of Development	*Preoperational*		*Concrete Operational*			*Early Formal Operational*			*Formal Operational*			
Types of curriculum experiences needed to achieve stated goals			1. Development and refinement of observational and descriptive skills and other process skills 2. Development of *concepts necessary for the production and processing of information* Property-interaction-system Relative position and motion Variable-equilibrium 3. Relevant themes important in life of student and society such as ecosystem 4. Use of instruments to extend senses			1. Explore wide range of areas in science 2. Practice in forming generalizations from concrete data—increasing in generality and degree of abstractness; data collected by individuals may be combined with group for analysis, or may be interpreted on an individual or small group basis 3. Practice making and testing deductions based on generalizations discovered by the student or provided by another source 4. Experimentation, both exploratory and testing of hypotheses with increasing emphasis on control of variables			1. (Grade 9) Begin Focusing on development of abstract models of structuring data 2. (Grade 10-12) Develop conceptual structure of disciplines 3. Interrelate abstract models and continue development of structure of science with conceptual schemes 4. Individual or group researches (seminar) or unsolved problems of science 5. Formal study of History and Philosophy of Science (seminar)		
Develop rational powers	----------Continuous use at all levels---------->											
Method of inquiry			Guided inquiry: Materials, teacher interaction, and questioning provides direction			Discovery oriented: Increasingly learner directed			Full spectrum of inquiry: Guided inquiry-free inquiry by student; development of structure relationships; special investigations			
Mathematical orientation			*Qualitative generally*			*Increasingly quantitative*			*Mathematically oriented*			
Focus in the development of science literary			Spirit of inquiry: begin development of processes, skills and ideas necessary to develop structure			Spirit of inquiry: develop a reservoir of conceptual building blocks—laws or principles in science			Spirit of inquiry: develop and interrelate conceptual models into a comprehensive structure			

Renner, John and Don Stafford. Teaching Science in The Secondary School. Harper and Row, Inc., New York, 1972.

The following diagrammatic presentation of student activity examples clarifies the differences between these two approaches. Remember, however, the development of all the attributes and objectives of the philosophy as listed in Chapter One can be accomplished through either approach.

	Approach I (Unrelated Activity)	Approach II (Coordinated Activity)
First Day -	Observe and record differences between a frog and a toad.	Observe and record differences between a frog and a toad.
Second Day-	Observe and classify a sack of rocks.	Determine if there are differences between how far a frog and a toad can jump.
Third Day -	Experimentally determine which kind of cloth, cotton or wool, absorbs water faster.	Determine if there are differences between how cold temperatures affect a frog and a toad.
Fourth Day -	Develop a set of data relative to different rubber balls and predict which will bounce highest.	Determine if there are differences between how a frog and a toad react to salt water.
Fifth Day -	Obtain and graph the data relative to the number of petals which a particular wild flower species has.	Observe and determine how a toad and a frog eat.

Figure 4
Types of Inquiry Approaches

The second approach is the more systematic of the two. Its very nature suggests investigatory types of activities and, consequently, the curriculum which utilizes this approach will reflect the operations basic to science. A more detailed examination of this approach will reveal how the operational utilization of some science and rational processes are achieved in the individual activities. Each activity is listed with the kind of science and rational process inclusion which one could expect. Typically, these could vary for each local system.

"What kind of science content is learned in the previous activities?" This is a valid question. It is obvious from the presentation which kinds of science and rational processes have been structured into the activities. Not so obvious, however, is the content which the activities present. The frog and toad have been used as the vehicles to promote the previously identified processes. Much content is learned relative to the animals' external anatomy and their behavior toward external stimulants, with all the learning coming through first-hand experiences with the toad and frog.

Another question which might be asked relates to the grade level of the previous activities. Because the processes which have been structured into the investigation are characteristic of the higher level of the learner's psychological development, the activities must be placed at the upper grade levels.

The Complete Curriculum. The total science curriculum must accommodate all learning levels from kindergarten through grade 12. Obviously, this will require a great amount of time from all involved in designing the activities. The combined activities from all levels can best be presented in the form of a science curriculum guide for the local system.

This local guide, if based on the philosophy from Chapter One, can be the foundation of a solid inquiry program.

The locally designed program must never turn into the traditional "hodge-podge" approach of expecting each individual teacher to be responsible for designing the activities and obtaining the materials necessary for the program under his guidance. Administrators must be responsible for maintaining the entire program through cooperative planning with individual teachers.

The value of a local guide comes from its being designed to meet local educational needs. The curricular activities can be designed to take advantage of local resources and local educators are involved in designing their own program.

There are many programs which are promoted as being inquiry-centered. Before adopting any of these programs be certain it meets the criteria for an elementary school science program set forth in Chapter One.

THE LOCALLY DEVELOPED CURRICULUM MODEL #2

Every school district has a responsibility for curriculum development. The need for change must be recognized before any progress can be made to bring the science program up to date with present trends and current research. The needs and wishes of faculty, students and community should be considered in the curriculum design and the choice of materials.

Three phases are usually involved in curriculum development: evaluation of the present program, planning for curricular change, and implementation of the new curriculum. For a detailed explanation of science curriculum development, the science advisory committee may wish to study the "Science Curriculum and the States" developed by the Council of State Science Supervisors and from which some of the following information has been obtained.

Evaluation of Present Program

In choosing or designing a curriculum for science education, consideration should be given to a philosophy, needs of the present program, and current trends in science education. Evaluation of the existing science program to determine areas of deficiency or weakness must occur before new programs are considered for adoption. The following questions may serve as a guide.

1. Is the science program directed toward certain realistic and worthy objectives?
2. Does it develop intellectual skills of scientific inquiry?
3. Is it based on pupil experiences and activities?
4. Does it develop laboratory skills?
5. Does it promote understanding of basic concepts?
6. Does it develop an appreciation of the scientific enterprise?
7. Is it multi-media oriented?
   Are materials available?
   Are materials appropriate to program objectives?
8. Is it a planned sequence of science instruction on a K-12 basis?
9. Is it organized but flexible and adaptable to diverse learning styles and teaching strategies?
10. Are student needs being met?
    What needs are not being met?
    What segment of the student population is not served?
11. Is it up-to-date in learning techniques as well as in scientific developments?
12. Does it emphasize interrelationships of science, technology, society, and other curriculum areas?
13. Is it understandable and appealing to the students for whom it is designed?

Planning A Curricular Change

When a program has been evaluated and need for change is recognized, there must be an organizational plan to assure effective curriculum development. This plan should include the administrator, the curriculum supervisor, the classroom teachers, interested school patrons, parents, consultants, and students. In planning for change in the science curriculum, local school districts have three options:

1. adoption of commercial programs
2. adaptation of commercial programs
3. creation of new programs.

If the school district has a science consultant, this person should be responsible for the selection of a curriculum committee. If such a person is not available, a science advisory committee should be formed from the lead teachers of the school or a lead teacher from each school in the district. This committee should consider identification of desired

educational objectives, local conditions and needs, recognition of socio-economic conditions and orientation to the local environment. They should also survey new science programs in accordance with national trends.

State or local textbook adoption should not inhibit experimentation and testing of new programs. In considering new science programs for adoption, the following factors should be considered:

1. Will the program use available materials to meet stated educational objectives?
2. Will it teach behavioral change?
3. Does it use inquiry-centered experiences as opposed to a subject centered approach?
4. Is it developmental in sequence (based on levels of cognitive development rather than on topic sequence)?
5. Do the suggested methods reflect sound learning theory and recent pedegogical know how?
6. Has the program been adequately tested?
7. Is there provision for a wide range of learning abilities and styles? If not, for what type of student is it intended?
8. What will it cost to implement? Is the cost feasible in terms of obtainable funds?
9. What changes will be necessary in personnel, time, space?
10. Is special teacher training necessary and, if so, are consultants available for this?
11. Does the package include all necessary materials or must the teacher still obtain certain things locally or by order?
12. What content areas are emphasized?
13. Can the program be coordinated with existing science programs or with the proposed curriculum?

Role of the Teacher

Since the teachers are the key agents in curricular change, it is important that they have a part in the study of materials and choice of them. It is essential that they understand the rationale and techniques necessary for implementing the materials and accept the curriculum design if they are to be successful in teaching it.

Probably the greatest teacher involvement comes in the trial classroom and evaluation stages where quantitative data as well as subjective judgements must be collected and fed back to the curriculum committee for consideration. When possible, it is wise to test some materials before purchasing a major commercial program. After testing, the following questions may aid in the evaluation:

1. How were the materials used?
2. What occured when the materials were used?

3. What did students do? What did the teacher do?
4. What can students do now that they have used the materials?
5. What attitudes and perceptions do students hold about the materials and content?

A new curriculum is not something that can be installed completely at any given time; but rather, it is to be gradually put into effect as decisions are made regarding staff and resources. Constant adaptation and evolution of the program will be accomplished by teacher feedback and team planning. No project developed is the final answer-teachers must adapt materials to their own situations and to their own students.

Role of the Community

Parents want to know what is going on in their schools, and become involved, but science has become so sophisticated that parents and other school patrons often feel left out. Members of the community may become involved by initiating curriculum change. For example, a community with a specialized industry, such as aerospace technology, may want aerospace science courses in the school. It is important that the community be informed of the nature of the experimental materials and methodology. Public schools are the people's business and involving a variety of people in the changes and decisions enhances the success of the programs.

Role of The Administrator

The administrator must know the present state of science education within his district and must help in planning for continual improvement. This is essential if the science curriculum is to effectively serve the entire range of students, from those who end their formal science study early to those who become professional scientists and engineers.

He is in a position to be able to work out lines of communication for continuous study and revision and make efficient use of available staff facilities, and funds for the program. Cooperation and assistance of all personnel is needed for effective implementation of a new science instructional program on a district-wide basis.

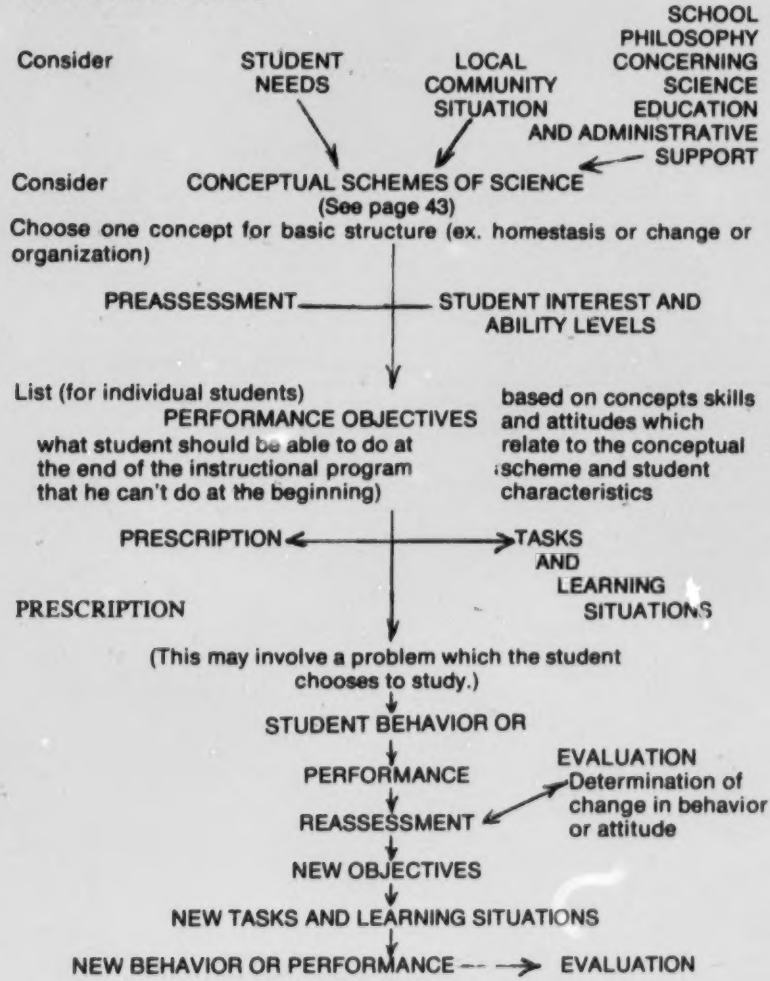
Role of The Local Science Coordinator

The science coordinator is responsible for:

1. surveys on the effectiveness of current programs
2. contracts with federal and state agencies, foundations, and industries for the procurement of funds and support
3. contact with professional societies and institutions for resource people and materials
4. identification of master teachers to assist with the program
5. dissemination of information to all school personnel

6. piloting new programs
7. coordination of curriculum
8. teacher inservice education

CONSTRUCTION OF CURRICULUM MODELS


Consider
STUDENT NEEDS
LOCAL COMMUNITY SITUATION
SCHOOL PHILOSOPHY CONCERNING SCIENCE EDUCATION AND ADMINISTRATIVE SUPPORT
Consider
CONCEPTUAL SCHEMES OF SCIENCE
(See page 43)
Choose one concept for basic structure (ex. homestasis or change or organization)
PREASSESSMENT
STUDENT INTEREST AND ABILITY LEVELS
List (for individual students)
PERFORMANCE OBJECTIVES
what student should be able to do at the end of the instructional program that he can't do at the beginning)
based on concepts skills and attitudes which relate to the conceptual scheme and student characteristics
PRESCRIPTION
TASKS AND LEARNING SITUATIONS
PRESCRIPTION
(This may involve a problem which the student chooses to study.)
STUDENT BEHAVIOR OR
PERFORMANCE
REASSESSMENT
EVALUATION
Determination of change in behavior or attitude
NEW OBJECTIVES
NEW TASKS AND LEARNING SITUATIONS
NEW BEHAVIOR OR PERFORMANCE
EVALUATION

This continuum should involve concept, skill and attitude development.

Suggest Conceptual Schemes For Science
From the NSTA Publication "Theory into Action"

1. All matter is composed of units called fundamental particles; under certain conditions these particles can be transformed into energy and vice versa.

2. Matter exists in the form of units which can be classified into hierarchies of organizational levels.

3. The behavior of matter in the universe can be described on a statistical basis.

4. Units of matter interact. The bases of all ordinary interactions are electromagnetic, gravitational, and nuclear forces.

5. All interacting units of matter tend toward equilibrium states in which the energy content (enthalpy) is a minimum and the energy distribution (entropy) is most random. In the process of attaining equilibrium, energy transformations or matter transformations matter-energy transformations occur. Nevertheless, the sum of energy and matter in the universe remains constant.

6. One of the forms of energy is the motion of units of matter. Such motion is responsible for heat and temperature and for the states of matter: solid, liquid, and gaseous.

7. All matter exists in time and space and, since interactions occur among its units, matter is subject in some degree to changes with time. Such changes may occur at various rates and in various patterns.

Science Process Skills

Students should develop skills including:

1. Observing
2. Classifying
3. Inferring
4. Predicting
5. Measuring
6. Communicating
7. Interpreting Data
8. Making Operational Definitions
9. Formulating questions and Hypotheses
10. Experimenting
11. Formulating Models

RECOMMENDATIONS CONCERNING THE PREPARATION OF SECONDARY SCIENCE TEACHERS

There is a need for college teachers to take a critical look at the instructional procedures of their courses as well as at organization and content. If teachers are expected to teach science by method of inquiry with real understanding, they must experience inquiry in the science courses they take. *It is impossible to accomplish this in a methods course alone.*

The Role of the Teacher Education Institution

The processes of scientific inquiry are as important as the concept developed. These processes include investigating, observing and reporting results of investigation, formulating and stating hypotheses, classifying materials, organizing and interpreting data, and making generalizations.

The education of elementary teachers in science must be viewed as a continuous process in both pre-service and in-service. *The preparation needed in most instances differs from the typical introductory college course in both scope and emphasis.* The scope must be much broader by emphasizing the nature of scientific inquiry. The elements must be obtained by providing:

Learning experiences which lead to increased understanding, knowledge, and skills in science appropriate to the needs and intellectual level of the children;

A study of the historical development and philosophy of science;

An awareness and appreciation of the expansion of knowledge and changing emphasis in science teaching.

Student teaching experience of many kinds, especially laboratory and field experiences with children.

Special Science Courses for Elementary Teachers

The program in science for the elementary teacher must include work from the biological, physical and earth sciences. The courses must be organized and taught using the method of inquiry. Planning these courses does not require that they be organized according to traditional disciplines. It is becoming increasingly more difficult to separate the various scientific disciplines and to separate the sciences from their social implications. There should be provision for individual and group laboratory experiments. Demonstrations performed by the instructor are not adequate substitutes for students' laboratory work. They should be utilized for illustrative techniques and to stimulate scientific thought, but opportunities must also be provided for students to develop scientific processes through designing and conducting their own laboratory investigation. Teachers tend to teach as they are taught, therefore, if

science is taught by inquiry the probability of their teaching by inquiry increases. If teachers are to guide children to develop confidence to inquire, they must first develop that confidence themselves.

Professional courses For Elementary Teachers

There should be provisions for gradual induction into teaching through a planned sequence of experiences including observation of elementary school programs in science culminating in a period of full-time supervised student teaching. The professional courses specifically designed to develop skill in teaching science in the elementary schools should include:

Systematic consideration of purposes, methods, materials, and evaluation procedures appropriate to the teaching of science;

Provisions of opportunities for the development of individual creativity in conducting experiements, planning other types of learning activities, developing teaching resources, and devising demonstrative equipment and procedures;

Study of the intellectual levels concept as the basis for work in the area of teaching methods and curriculum planning;

In addition to the pre-service preparation program in science for the elementary teacher, serious thought must be given to helping the teacher already on the job. In-service programs designed to facilitate the implementation of an inquiry centered science program at the local school level must be provided by the State Department of Education, colleges and universities, and local administration units. These programs must be so planned that the scientists, science educators, supervisors, and others work as a team to help the teachers understand the nature of the inquiry approach; develop the needed materials; secure suggestions for program development and implementation; adapt to local needs; and provide procedures for evaluation.

RECOMMENDATIONS CONCERNING THE PREPARATION OF ELEMENTARY SCIENCE TEACHERS

We feel there is a definite need for college and university teachers to take a critical look at the instructional procedures within their courses as well as the total course organization and content. If secondary teachers are to be expected to teach science by the method of inquiry with any real understanding, they must experience inquiry in the science courses they take in their professional science training in college; it is impossible to accomplish this point of view in a methods course alone.

The processes of scientific inquiry are of the same order of importance

as the conceptual information desired. Ability to use inquiry can only be developed by experiencing satisfaction with it. This process includes: investigating, observing and reporting results of investigations, isolating and testing variables, stating hypotheses, designing and conducting investigations, using various measuring devises, classifying materials, organizing and interpreting data, and making generalizations.

The education of secondary science teachers must be viewed as a continuous process—both pre-service and in-service. The preparation needed, in most instances, differs in both scope and emphasis from that typically available in most introductory college courses.

The scope must be much broader with emphasis on the underlying concepts, scientific principles, and the nature of scientific inquiry. The elements must be obtained by providing:

1. Learning experiences which lead to increased understanding, knowledge, and skills in science and mathematics.
2. Opportunities to increase understanding of science and mathematics problem solving, critical thinking, and methods of inquiry.
3. Learning experiences which lead to understanding the relationships between branches of science and mathematics and between these area and other branches of learning.
4. Opportunity for the study of the historical development and philosophy of science.
5. Awareness and appreciation of the expansion of knowledge and changing emphasis in science and mathematics.
6. Awareness on contemporary scientific developments.
7. Experiences of many kinds, in working with children, especially laboratory and field experiences, which illustrate the methods of science.

Science courses pursued by the secondary teacher in college must be organized and taught using the philosophy of inquiry with emphasis on: the nature of evidence, the process of measurement and instrumentation, the interrelationship of all areas of science and mathematics, and the ability to understand abstract relationships. These courses must be taught by professors who are interested in and understand the philosophy of inquiry and who are provided time to plan and prepare for the classroom.

In developing courses for secondary teachers, consideration should be given to the notion that they need not be organized according to traditional disciplines. The inquiry approach to teaching science is not concerned with science as a distinct discipline but as a composit unit. ***The nature of the science programs advocated in this guide requires that colleges and universities develop interdisciplinary courses in order to provide the teacher with the experiences necessary to deal with the philosophy of the courses advocated. This will require new courses designed to meet the special needs of the new curricula.***

Separating the various scientific disciplines and to separate the sciences from their social implications is becoming increasingly difficult. There should be provision for individuals and group laboratory experiments.Demonstrations performed by the instructor are not adequate substitutes for students' laboratory work; they can and should be utilized for illustrative techniques and stimulative scientific thought. Opportunities however, must also be provided for students to develop their ability to inquire through designing and conducting their own laboratory investigations.

During the pre-service preparation for secondary teachers, in addition to the required science course, there should be a laboratory course in experimental procedures and scientific techniques as they apply in the presentation of science to the secondary school child. The preparation program should emphasize the teaching of science processes through inquiry.

There should be provision for gradual induction into teaching through a planned sequence of experiences including observation of secondary school programs in science culminating in a period of full time supervised student teaching. This entire experience should be accomplished over a period of three or four semesters and not just for a few weeks during one semester. The professional courses specifically designed to develop skill in science teaching for the secondary schools should include:

1. Systematic consideration of purposes, methods, materials, and evaluation procedures appropriate to the teaching of science.
2. Attention to the indentification and development of teaching procedures appropriate to the abilities of the individual.
3. Study of a number of different approaches to teaching science, research in science, and current trends and developments.
4. Provision of opportunities for the development of individual creativity in conducting experiments, planning other types of learning activities, developing teaching resources and procedures.
5. Study of the psychological characteristics of learner.
6. Experiences in analysis, study, and development of curricula.

In addition to the pre-service preparation program in science for the secondary teacher, serious thought must be given to the teacher already on the job who needs help.

In-service programs designed to facilitate the implementation of an inquiry-centered science program at the local school level must be provided by the State Department of Education, colleges and universities, and local administration units. These programs must be so planned that scientists, science educators, supervisors, and others work as a team to help the teachers understand the nature of the inquiry approach; develop the needed materials; secure suggestions for program development and implementation; adapt the local needs; and provide procedures for evaluation.

It is recognized that improvement in science instruction in the Oklahoma schools inevitably requires improvement in the preparation of the teachers of science. This is the responsibility of the colleges and universities; however, the teacher education programs in the colleges and universities are greatly influenced by the certification requirements established and enforced by the State Department of Education.

The committee makes the following recommendations:

1. All teachers of courses designated as science courses in the secondary schools, should have a Natural Science Teaching Certificate. This would include teachers of 7th and 8th grade science courses.
2. Before receiving the highest level of professional certification, the committee recommends that teachers be required to have a master's degree with specialization in science.

NATIONAL SCIENCE CURRICULUM ORIENTATION

The following excerpts are reproduced from THEORY INTO ACTION . . . IN SCIENCE CURRICULUM DEVELOPMENT, National Science Teachers Association, Washington, D.C., 1964.

"The National Science Teachers Association takes the position that to be fully adequate the school science program:

1. Must start as early as kindergarten or first grade;
2. Must be articulated from one level to the next through grade twelve or higher;
3. Must encompass a full range of the contemporary knowledge and ideas which scientists employ;
4. Must result in understanding the nature of the scientific enterprise through direct student involvement in the processes of scientific inquiry;
5. Must involve the best that is known about child growth and development and the psychology of learning; and
6. Must be supported by first-rate staff, facilities, and instructional materials.

"With regard to evaluation . . . This process should be closely tied to the stated objectives of a given curriculum . . . where the evaluation of a given set of goals turns out to be difficult, this should not be taken as indicating a weakness in the goals, but rather as a weakness in our knowledge of evaluation . . . No single program can or should be designed for use in all or even a majority of the school districts of the nation. Multiple efforts in curriculum development should be encouraged which involves creative and diverse approaches."

Curricular Programs

The following programs are among those which meet major objectives for students of science. Special teacher training is highly desirable.

Name of Program	Content	Level	Source	Necessary Space
Science A Process Approach (S-APA)	Wide coverage, various fields of science, some math & social studies—process skills	K-6	Xerox Ed. Group—Distribution Center 555 Gotham Parkway, Carlstadt, N.J. 07072	Regular Classroom
Science Curriculum Improvement Study (SCIS)	Ungraded, sequential physical & life science	K-6	Rand McNally P.O. Box 7600 Chicago, Ill. 60680	Regular Classroom
Elementary Science Study (ESS)	Ungraded, modular, non-sequential units of wide range could be used with non-readers	K up	Webster McGraw Hill-Manchester Rd. Manchester, Missouri 63011	Regular Classroom
Intermediate Science Curriculum Study (ISCS)	Energy, Matter, process skills for heterogeneous groups & special activities for scientifically talented	7-9	Silver Burdette General Learning Laboratory 250 James St. Morristown, J. 07960	Classroom Lab
Interaction Science Curriculum Project (ISCP)	Lab oriented program for heterogeneous groups & special activities for scientifically talented	7-9	Rand McNally P.O. Box 7600 Chicago, Ill. 60680	Classroom Lab
Interaction of Man and the Biosphere	Life Science	7		
Interaction of Earth & Time	Earth Science	8		
Interaction of Matter & Energy	Physical Science (see description in S.C. Adopted Textbooks)	9		
Investigating the Earth—Earth Science Curriculum Project (ESCP)	The Earth Sciences for scientifically talented. If Activities stressed, Heterogeneous Classes can use this lab approach.	8-9	Houghton Mifflin 666 Miami Circle, N.E. Atlanta, Ga. 30325	Classroom Lab
Life Science Investigations Man & The Environment (ERC-Life Sci.)	Life science with ecological emphasis—useful for heterogeneous groups	7-8	Houghton Mifflin Co. 110 Tremont St. Boxton, Mass. 02107	Classroom Lab
Me Now	Life Science for non-reader	Mentally handicapped (M.A. 5-9)	Hubbard Scientific Co. Box 105, Northbrook, Ill. 60062	Classroom lab

Necessary Materials	Basic Teacher Training	Approximate Initial Cost (Class of 30)	Type of Structure
Instructional materials for teachers, commentary for teachers, extra kits of teaching aids	Inservice training necessary consultant training available—Guide for in-service training	$500	Highly structured Sequential
2 kits of instructional materials each level (1 life, 1 physical)	Inservice training necessary consultant help, conferences, workshops	$125-$200	Moderately structured
Choice by units-teacher manuals available (extra)	Consultant & workshops	$12-$150	Loosely structured
Student texts, Teachers' guide Master set for students section sets	Consultant services Conferences, institutes	Master set for 5 sections of 30 students each $788	Moderately structured
Text Teachers' guide Lab materials	Consultant service, workshop	$375 if kit purchased Most material can be obtained locally	Highly structured
Teacher instructio materials Laboratory equip. Package separate kits	Consultant services—inservice training desirable	Complete class asst. $789 minimum $450	Highly structured as written but adaptable
No kits-learning games-basic life-science equip. needed	Life science background helpful	Class set including printed materials and learning games $42.15	Moderately structured
4 units instructors guide daylight slides, film loops	Life science background	$400-$500	Loosely structured

Name of Program	Content	Level	Source
The Man-Made World Engineering Concepts Curriculum Project (ECCP)	based on a "Systems" approach to solving social and environmental problems interdisciplinary emphasizes technological literacy	11-12	Webster-McGraw-Hill
Chemistry: An Investigative Approach (Chem Study)	emphasis on experimentation, observation and measurement leading to understanding of concepts. Opportunity for discovery (see State Adopted Text)	11	Houghton Mifflin
Chemistry Experimental Foundation	Same as above	11	Prentice-Hall
Ideas and Investigations in Science Physical Science	5 major ideas taught using a lab approach. predicting, matter, energy, interaction, technology, designed for the "educationally uninvolved" poor reader, potential drop-out; stress success	9-10	Prentice-Hall
Biology	5 major ideas: inquiry, evolution, genetics, homeostasis, ecology		

Introductory Physical Science (IPS)	lab approach to Physical Science—lab activities are part of text (see State Adopted Text description)	9	Prentice-Hall
Biological Science, An Inquiry Into Life (BSCS Yellow)	emphasis on cell and organismic levels of Biology for average and above (see State Adopted Text)	10	Harcourt, Brace & Javanovich
Biological Science: Molecules to Man (BSCS Blue)	for above average (see State Text Adoption) Biochemical evolutionary approach	10	Houghton Mifflin
High School Biology (BSCS Green)	for average and above (see State Text Adoption) Ecological approach	10	Rand McNally
Biological Science: patterns and Processes	for below average (see State Text Adoption)	10	Holt, Rinehart, Winston
Physics (PSSC)	average and above (see State Text Adoption)	12	Heath
The Project Physics Course (HPP)	broad, humanistic, lab oriented approach	12 9th grade reading level	Holt, Rinehart Winston

Sets of cards for each problem Teacher's guide	Consultant services available	$466.40 and lab materials usually found in high school
Necessary Training	**Teacher Training**	**Approximate Initial Cost**
Text Lab manual Teacher's manual Lab equipment	Methods of instruction include: independent study, lab investigations, seminars & discussion groups, computer simulations. Training is recommended and available	$1,000-$4,000 depending on present inventory of equipment
Text and lab in a single volume Teacher's guide	Consultants and institutes for training are available but not essential	Basic chemical equipment and supplies only
Text Lab manual Teacher's guide	Same as above	Same as above
5 paperbacks (1 for each idea) or 1 text and student lab book Teacher's guide Lab materials	Consultant available	May use local materials if package is purchased cost range is per package
Same as above	Same as above	Same as above

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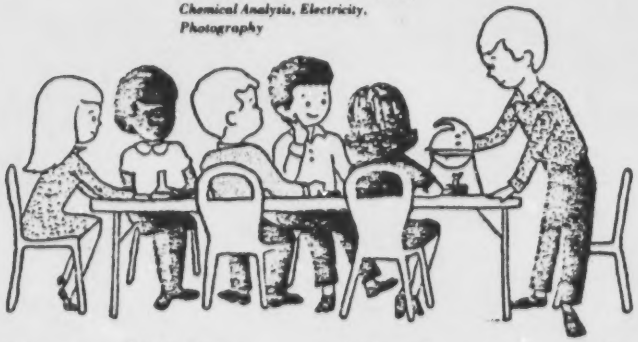
Text Teacher's guide Specially designed materials	Consultant services available	$678 highly structured		
Text Teacher's guide Lab book	Consultant available	Basic biology materials no special equipment		
Text (lab included in text) Teacher's guide	Same as above	Same as above		
Same as above	Same as above	Same as above		
Same as above	Same as above	Same as above		
Text Lab manual Teacher's guide Films available	Consultant available			
Text Handbook, Teachers' Resource Books, Readers, Programmed instruction booklets, (Average materials available)				
Science Problems (ERC Sci Problems)	lab science course for those who do do not take chemistry and physics; individualized, interdisciplinary, problem centered, modules. Titles include: *Plant Growth, Slot Car Science, Survival, Behavioral Science, Chemical Analysis, Electricity, Photography*	11 & 12 Not commercially published		



Necessary Materials	Basic Prog. Teacher T	Initial Cost (Class of 30)	Type of Structure
Natural basic science equipment		Minimal	Loosely structured
Easily obtainable		Minimal	Moderately structured
Soft & hardback texts, lab books		Minimal	Moderately structured

Modules		Minimal	Moderately structured
Student, class teacher equip. packages (No text) Science Reading Series	Training program recommended Consultant services	$409 (for 30) Does not include printed materials	Loosely structured
Natural		Pks. 1 and 2 $10 Teaching non-guide	Open-supplementary-not a total program
Instructional materials	None	Varies	Moderately structured

ADDITIONAL MATERIALS

Name of Program	Content	Level	Source	Necessary Space
People and Their Environment	Environmental education (interdisciplinary) useful for heterogeneous groups	1-12	Copies distributed to all S.C. schools additional copies J. G. Ferguson Pub. Co. 6 N. Michigan Ave. Chicago, Ill. 60602	Classroom & outdoor
Addison-Wesley Environmental Studies Series	Air, water, noise pollution	Open	Addison-Wesley Pub. Co. Menlo Park Reading, Mass.	Classroom & outdoor
Pathways in Science	Modular biology, earth science, chemistry, physics	7 up Written on lower 5 and 6 grade level	Globe Book Co. Dept. B-20 175 Fifth Ave. New York, N.Y. 10010	
Middle School Life Science Proj. of BSCS	Multi-disciplinary	6-8 integrated program designed specifically for middle school student for heterogeneous groups	BSCS P.O. Box 930 Boulder, Colo. 80302	Being developed to be tested in classroom Sept. 1972

Time, Space and Matter	Physical science geology, astronomy, physics, chemistry, math. Interdisciplinary, could be used with non-readers and heterogeneous groups 9 sequential investigations	8, 9, 10	Webster McGraw Hill, Manchester Rd. Manchester, Mo. 63011	Classroom Lab
Environmental Studies Packets (ES)	Suggestions for exploring the environment, useful with non-readers, heterogeneous groups, and interdisciplinary programs	K-12	Environmental Studies Project Box 1559 Boulder, Colorado 80302	Outdoor classroom
Individualized Science Instructional System (ISIS)	A variety of minicourses, topical coverage, inquiry approach	7-12	Ginn and Company, Xerox Education Company, Lexington, MS 02173	Regular classroom

CHAPTER III

ACTIVITIES THAT SUPPORT SCIENCE EDUCATION

MATHEMATICS, ESSENTIAL TO A SCIENCE PROGRAM

Just as the hammer is a basic tool for the carpenter, mathematics is a necessary and vital tool used by the scientist. One would not expect the carpenter's work to progress far without the aid of the hammer. Likewise, scientific activity would be severely restricted without the aid of mathematics. At best, scientific observations could only be of a qualitative nature. The utilization of mathematics permits the investigator to quantitate his observations.

The secondary science curriculum must reflect this mathematical emphasis if the course structure is to parallel the work of the scientist. Far too often, the secondary science program suffers when mathematics is omitted. This has resulted in descriptive science courses. There is no reason why the artificial boundaries can't be removed so that secondary science and secondary mathematics can be fused by the learner. A science program can only be valid in its processes if it is supported by an adequate usage of mathematics.

Teaching Children to Measure

METRICS

With the introduction of metric units, an attempt should be made to bring the teaching of measurement in line with current knowledge about how children learn to measure. The organizational structure for programs of measure must be sufficiently broad to include instruction on nonstandard units as well as standard units of measure. Instruction at all grade levels should take into account the major learning processes that are important to the intellectual development of the child.

Measurement is a procedure for comparing what is to be measured with a suitable standard; this idea about measurement unifies both ancient and modern systems of measure used by man. The historical development of the methods of measure used by man provides a natural model for instruction. This model consists of four increasingly complex stages:

1. Making direct comparisons between objects to find their relative measure.
2. Using some convenient nonstandard unit to make comparisons.
3. Comparing objects to be measured with a selected standard (SI).
4. Reducing the errors of measure by choosing units of appropriate size.

Using the four stages of measure identified above, activity oriented measurement programs may be developed by organizing the activities provided children around the following learning processes:

1. Language development
2. Estimation

3. Simple matching and comparison
4. Ordering
5. Simple relations and mapping
6. Pictorial representations

Conservation Abilities

Piaget maintains that conservation is a necessary condition for understanding almost any notion, whether it is scientific, mathematical, or just a matter of common sense. Conservation is defined as the ability of the child to maintain that a particular property possessed by an object (length, mass, volume, etc.) remains unchanged despite changes that may occur in irrelevant aspects of the object.

Children gain the ability to conserve certain quantities at different ages. When about 75 percent of the children in a particular age group can conserve a particular quantity, they are said to be able to conserve that quantity. The ages at which children may be expected to conserve such quantities as a number length, mass, etc., are as follows:

Table 1	Age Span
Conservation of number	6-7.5 years
Conservation of length	7-8.5 years
Conservation of mass	9-10 years
Conservation of solid volume	11-13 years
Conservation of displaced volume	13-15 years

Piagetian tests of the child's ability to conserve length, distance, mass, liquid capacity, volume, etc., provide formal evidence of the child's understanding of measurement concepts. Informal observations of how readily the child is able to perform different types of measuring activities provide further information. Even though a child appears to be ready to use standard units of measure, extensive work with metric units should not be attempted until he is able to conserve the quantity he is being able to measure.

Why Metric?

The present national concern for metrication historically dates back to 1968 when Congress passed a Metric Study Act. This concern appears to stem from three major areas of importance. They are:

1. increased use of the metric system in the United States;
2. the need for an international standard; and
3. simplicity of the metric system as compared to the present system of weight and measures.

Increased Use of Metric

Within the last few years many prominent industrial organizations have announced a commitment to change over to metric measurement in their operations. Approximately eleven percent of American manufacturing companies already use the metric system to some degree. Pharmaceuticals and chemicals, the optics industry, microfilm industry, and some divisions of aircraft and automobile companies, among many others, now employ metric measurements. And the housewife has probably noticed that food labeling often includes grams as well as ounces on packages and cans.

The American National Standards Institute recently formed the American National Metric Council to help guide the change to metric for the industrial and commercial segments of our society. In addition, many key associations have adopted pro-metric resolutions. These cover a wide range of interests, and include the National Association of Manufacturers, the United States Chamber of Commerce, the National Education Association, the American Home Economics Association, and the National Grange.

Metrication is receiving much attention in the press. The nation's newspapers have carried an average of four to five articles on this subject since the United States Metric Study report was sent to the Congress in 1971. In this same period of time, nearly every paper has carried a metric editorial with interesting results: 91 percent were pro-metric; 7 percent were neutral; and only 2 percent were anti-metric.

Road signs giving distances and/or speed limits in both metric and customary units are appearing in several states. Perhaps the most notable is in Ohio, where their State Department of Transportation, as part of a program to introduce metric into their operations, began to erect dual marked distance signs early in 1973. Other states reported to have some such signs include Arizona, Maryland, Minnesota, Washington, Virginia, Michigan, and Pennsylvania.

The National Park Service, beginning in 1974, will add metric values to park signs and pamphlets for the benefit of the United States citizens as well as foreign visitors.

The Departments of Agriculture, Defense, and Health, Education, and Welfare have already employed the metric system in many activities. For example, the Department of Agriculture began using the metric system of measurement in its regular crop reports effective May 9, 1974.

In August, 1972 the Senate unanimously approved a bill to make the metric system predominant within ten years. The House of Representatives did not take action on this bill which forced the initiation of new legislation. Presently, there are bills before the House of Representatives and the Senate. While these bills may not be passed this year, probably in the near future the United States Congress will enact legisltion that will commit this country to metrication.

3 64

Need For International Standard

The primary reasons for the increasing use of metrics by our industries, which finds it necessary to change to international metric standards, are two fold. First, as an aide to maintaining and expanding our exports and secondly, as a means of avoiding the inefficiency and inconvenience of operations at home and abroad where they are manufacturing the same products to different standards.

The change to metric units of measurement is inevitable. Over 90 percent of the earth's population now lives in countries committed to the use of the metric system of measurement. In 1970 only the United States and a few small countries were not part of the metric world.

England, where our present system of units originated, has gone metric. Our neighbor to the north, Canada, is now in the midst of converting totally to the use of the metric system. The hope that our system would be adopted by other nations has faded and we can no longer afford to cling to it.

The Metric System is Simple

That the metric system is as much simpler than the one currently being used in the United States is a fact. Present nationwide metric publicity and promotion of the international metric system is confusing the public, however, and will retard acceptance of metric in America.

First, there are seven base units. They are the metre, kilogram, second, degree Kelvin, ampere, candela, and the mole. Of these only three will be of major concern to the public, the metre, base unit of length; the kilogram, base unit of mass; and degrees Kelvin, the base unit of temperature. The common unit for volume and capacity will be the litre.

Although the degree Kelvin has been chosen as the basic unit of temperature, the degree Celsius will receive more common acceptance These two scales are "identical" with exception of the zero reference points.

There are fourteen prefixes accepted as part of the international Metric System. Of these, only three will be of common concern to the general public. They are: kilo, centi, and milli.

There's another nice thing about the metric system everyone will appreciate. Since it is based on the decimal system, there are no fractions to contend with. You don't have to know fractions to handle money because the money is decimalized. You don't talk about one and four twenty-fifths dollars, you pay one dollar and sixteen cents. The same is true of the metric system.

When India changed to the metric system in 1956, they found that even

the people who couldn't read or write had no trouble learning the new system. Therefore, the metric system should be no problem for you.

In the conversion to the metric system, the greatest disadvantage for Americans would be in *acceptance of the changeover--not in learning the system itself.*

In researching the problems of metric transition, we have never found in a single simple book, data that would quickly update teaching personnel in the general principles involved.

Herein, we outline data we feel is urgently needed for use in the educational system.

Because metric --SI-- is still evolving, disagreement may be taken with some of our findings; however, at this stage it would not be improbable that this would not be the case.

With the United States' adoption of the metric system and the International System of Units (SI for short) this nation will be harmonizing its practices with the balance of the industrialized world.

This section outlines the basics of the new system in sufficient depth for updating personnel purely on the basis of limited study. Future personnel will undoubtedly be educated solely in metric terms and textbooks updated according: however, a critical need exists for publication for immediate use during the early stages of United States transition; thus this guide.

It explains the system and presents a list in ready-reference format of the recommended units.

Base Units and Supplementary Units

The modernized form of the metric system of units is known as the International System of Units (Systeme International d' Unites) adopted by the General Conference of Weights and Measures (CGPM) and sanctioned by the International Standards Organization (ISO).

The short symbol for the system is "SI."

The SI uses seven base units and two supplementary units. The units are:

ITEM	*NAME OF UNIT*	*SYMBOL*
BASE UNITS		
LENGTH	METRE	m
MASS	KILOGRAM	kg
TIME	SECOND	s
ELECTRIC CURRENT	AMPHERE	A
TEMPERATURE	KELVIN	K
LUMINOUS INTENSITY	CANDELA	cd
AMOUNT OF SUBSTANCE	MOLE	mol
SUPPLEMENTARY UNITS		
PLANE ANGLE	RADIAN	rad
SOLID ANGLE	STERADIAN	st

Prefixes - pronunciation & meanings

The common prefix listing was at one time greater in number than the fourteen now recognized in ISO STANDARD 1000; these prefixes are ample enough to cover all general consumer needs as well as the technical requirements of industry and research.

The prefixes are presented here by name spelling, symbol reference, diacritical marking, exponent form, decimal form, and descriptor respectively -- the order of presentation diminishes from largest multiple toward base unit one and then on to the smallest sub-multiple prefix.

1.	tera	T	tĕr'ə	10^{12}	1 000 000 000 000	one trillion times
2.	giga	G	jĭ'gə	10^{9}	1 000 000 000	one billion times
3.	mega	M	mĕg'ə	10^{6}	1 000 000	one million times
4.	kilo	k	kĭl'ō	10^{3}	1 000	one thousand times
5.	hecto	h	hĕk'tō	10^{2}	100	one hundred times
6.	deca	da	dĕk'ə	10^{1}	10	ten times
7.	deci	d	dĕs'ĭ	10^{-1}	0.1	one tenth of
8.	centi	c	sĕn'tĭ	10^{-2}	0.01	one hundredth of
9.	milli	m	mĭl'ĭ	10^{-3}	0.001	one thousandth of
10.	micro	u	mī'krō	10^{-6}	0.000 001	one millionth of
11.	nano	n	năn'o	10^{-9}	0.000 000 001	one billionth of
12.	pico	p	pē'kō	10^{-12}	0.000 000 000 001	one trillionth of
13.	femto	f	fĕm'tō	10^{-15}	0.000 000 000 000 001	one quadrillionth of
14.	atto	a	ăt'tō	10^{-18}	0.000 000 000 000 000 001	one quintillionth of

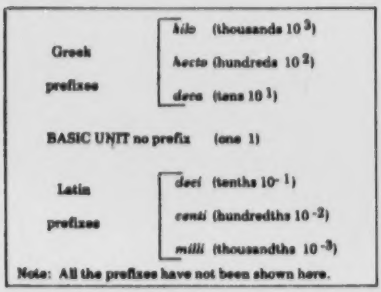
This prefix listing provides a convenience of choice for the appropriate multiple of the SI base supplementary/derived unit so as to lead the numeral value to within a practical utility range. Generally a multiple would be selected in such a manner as to allow the numerical value to be somewhere between 1 000 and 0.1 (for example, 3.94 mm as opposed to 0.003 94 m, or 12 kN as opposed to 1.2 X 10 4 N, or, 0.1 Mm or 100 km as opposed to 100 000 m, or 1,4 kPa as opposed to 1 400 Pa, and so forth).

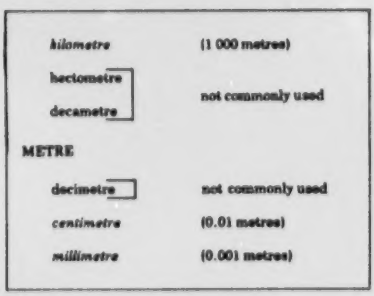
The Use of Prefixes in the Metric System

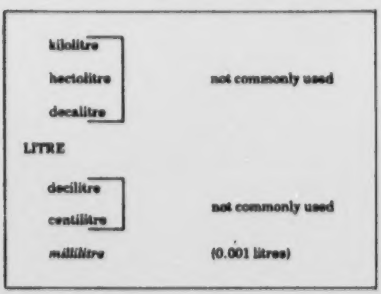
In the metric system the value of the common unit is changed by simply placing a prefix in front of it. With the three common units: metre, litre, and gram, the prefixes: "kilo", "hecto", "deca", "deci", "centi", "milli", etc. will change the quantity of the basic unit.

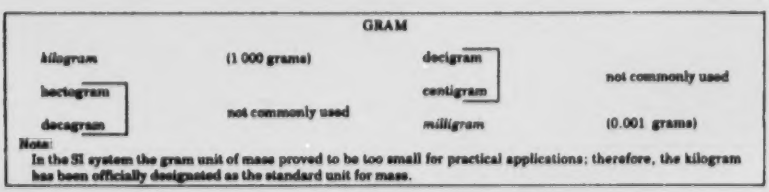
The relationship of these quantities is very simple once these basic units and assigned prefixes have become familiar. Some prefixes are used more commonly than others. Usually, multiples of 1 000 of the basic unit are preferred.

Illustrated Use of Prefixes



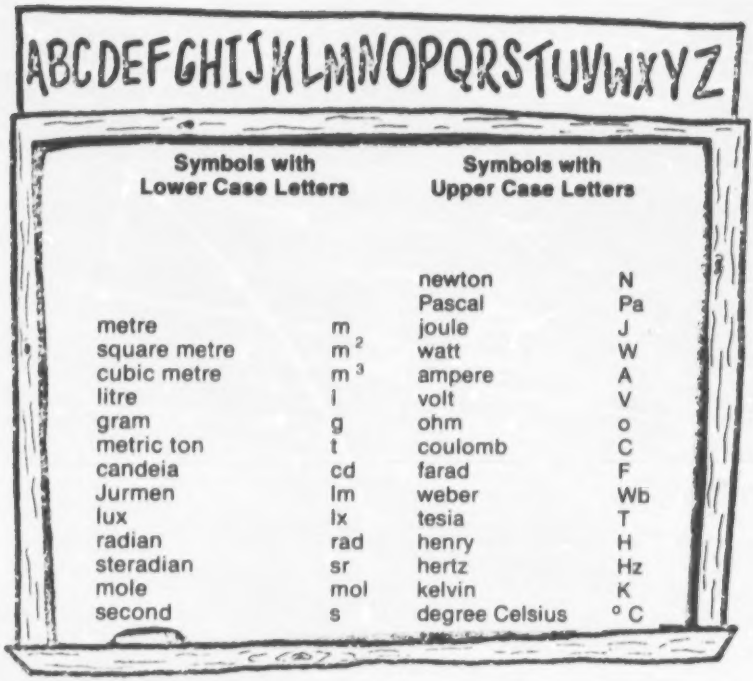





GRAM
kilogram (1 000 grams)
hectogram
decagram
not commonly used
decigram
centigram
not commonly used
milligram (0.001 grams)
Note:
In the SI system the gram unit of mass proved to be too small for practical applications; therefore, the kilogram has been officially designated as the standard unit for mass.

SI Symbols

With minor modifications these symbols are in accordance with the recommendations of the International Organization for Standardization (ISO).



Symbols with Lower Case Letters		Symbols with Upper Case Letters	
		newton	N
		Pascal	Pa
metre	m	joule	J
square metre	m^2	watt	W
cubic metre	m^3	ampere	A
litre	l	volt	V
gram	g	ohm	o
metric ton	t	coulomb	C
candeia	cd	farad	F
Jurmen	lm	weber	Wb
lux	lx	tesia	T
radian	rad	henry	H
steradian	sr	hertz	Hz
mole	mol	kelvin	K
second	s	degree Celsius	° C

Rules For The Use Of The International Metric System

Only one prefix can be used at a time. Compound prefixes are incorrect.

The *plural -s* is *never* used with metric symbols.

Metric symbols are always written *without a period*. Symbols may be raised to a power, but abbreviations followed by a period can not.

Square and cubic measure: Units of area and volume must be written with an exponent 2 and 3 respectively: m^2 , km^2 , m^3 , cm^3 (cc is incorrect).

Litre: An ordinary lower case "l" could, in some contexts, be mistaken for the figure 1; therefore, the symbol should preferably be written in italics, cursive, or else the word litre written out.

Whenever practical, *decimals* should be used instead of fractions: 0.75 instead of 3/4. Decimals are also preferred for computer application, as common fractions introduce complication in keypunching and programming.

There must always be a *space* between the numerical value and the symbol of the unit.

The *thousands marker:* Groups of three digits above and below the decimal marker should be separated by a small space (a full space in typing and one-half space in printing). The comma, which has traditionally been used for this purpose, is discouraged, in order to avoid confusion with the predominant practice in metric countries of using a comma instead of a decimal point.

If a numerical value is less than 1 (one) a zero must precede the decimal marker: 0.5 instead of .5.

Temperature: The degree symbol ^{o} is necessary with Celsius (^{o}C), in order to distinguish it from coulomb (C). But kelvin has no degree symbol. Although kelvin is the basic SI unit for (absolute) temperature, Celsius is the internationally current unit of temperature preferred for most practical applications. (For temperature interval: 1K = 1 ^{o}C). While it was, in English and French, at one time called "centigrade", Celsius is since 1948 the only official term in most countries, including Canada and the United States.

Symbols of units named after historic persons are written with upper case initials; all other symbols are lower case.

Prefixes: Only the symbols of the three highest prefixes "tera", "giga", and "mega" are written with upper case letters. All other prefixes must be lower case.

The preposition "per" indicating ration or the function division should, in SI symbols, preferably be written with an oblique stroke or solidus /. Speed: m/s; electric field strength: V/m.

Metric Definitions and Derived Un' .s

The *metre*, the basic unit of length in the metric system, is defined as 1 650 763.73 wave lengths in vacuum of the orange-red line of the spectrum of krypton 86.

Derived units:

Area - square metre
- hectare (10 000 square metres)

Volume and capacity - cubic metre
- litre

Because the gram is rather small, the *kilogram* has become the standard unit of mass in the metric system. The standard kilogram is based on a cylinder of platinum-iridium alloy kept by the International Bureau of Weights and Measures in Paris.

Derived units:

Force - 1 *newton* applied to a mass of 1 kilogram gives an acceleration of 1 metre/second squared.

Work or Energy - the force of 1 newton applied through a distance of 1 metre produces 1 *joule* of work done.

Power - 1 joule of work done in 1 second is 1 *watt* of power.

Pressure - 1 newton of force applied to an area of 1 square metre is 1 *pascal.*

The second, the basic unit of time in the metric system, is defined as the duration of 9 192 631 770 cycles of the radiation associated with a specified transition of the cesium atom.

Derived units:

Frequency - a frequency of one period (cycle) per second is called 1 *hertz.*

Speed or Velocity - metre/second.

Acceleration - metre/second/second.

The *candela* is the basic unit of luminous intensity in the metric system. It is defined as the intensity of 1/600,000th of a square metre of the cone of light emitted by a black body that has been heated to 2 042 Kelvins, the freezing point of platinum.

Derived Units:

Illumination - *lux.*

Luminous flux - *lumen*

The *mole* is the standard metric unit for the amount of a particular substance. It is defined as the amount of substance in a system that contains as many elementary entities as there are atoms in 0.012 kilograms of carbon 12. Moles are primarily used in physics and chemistry when discussing such things as atoms and molecules.

The *Kelvin* scale is used to measure temperature in the metric system. The Kelvin scale has its origin, or zero point, at absolute zero (the point at which all atomic vibration ceases) and a fixed point (273.16 Kelvins) at the triple point of water-0° Celsius (the temperature at which water exists in all three states - vapor, liquid, and solid). The Celsius scale is derived from the Kelvin scale and has 0° for the freezing of water and 100° as the boilding point.

The *ampere* is the basic unit of electric current in the metric system. It is determined by passing current through two parallel wires separated by a distance of one metre and then measuring the force of attraction between the wires, caused by their magnetic fields. The ampere is defined as the amount of current that will produce a force of exactly 2 X 10 newtons between the two wires for each metre of length.

Derived Units:

Electric potential - *volt*

Electric resistance - *olm*

Electric capacitance - *farad*

Electric charge - *coulomb*

Electric inductance - *henry*

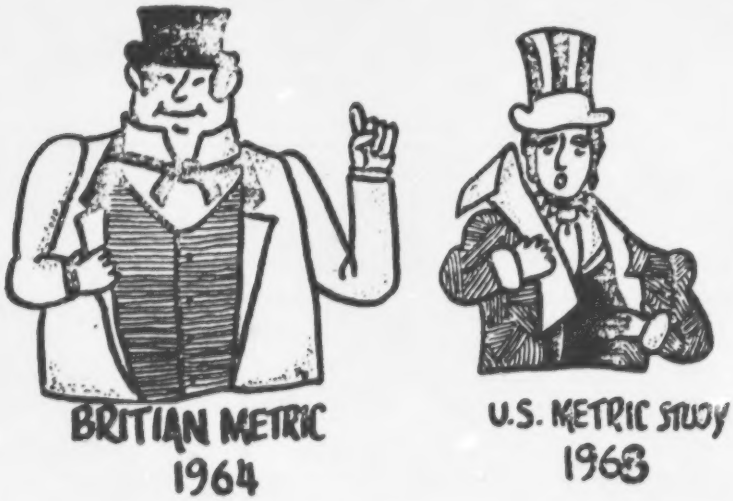
Magnetic flux - *weber*

Magnetic induction - *tesla*

SI Supplementary Units:

Plane angle or *radian*. The unit of measure of a plane angle with its vertex at the center of a circle and subtended by an arc equal in length to the radius.

Solid angle or *steradian*. The unit of measure of a solid angle with its vertex at the center of a sphere and enclosing an area of the spherical surface equal to that of a square with sides equal in length to the radius.



PROCEDURE AND CRITERIA FOR SELECTING TEXTBOOKS A science adoption occurs generally every four years. As a basis for computing the cycle, science textbooks are being presented and evaluated during the school year 1977-1978. Those texts selected will be available to schools beginning the school year 1978-1979.

Each science teacher should be aware of the structure for adopting textbooks. Primarily, it is a legislated function and it is dependent upon the operation of the State Textbook Commission. There are twelve educator members and one layperson member on the Commission. These members choose advisors to assist them in evaluating textbooks being bid for adoption. The examination and evaluation period generally begins in the spring and ends in the Fall.

Those texts selected are advertised via various methods i.e., a textbook caravan, media, drive-in conferences. . .

The Oklahoma Science Teachers Association has develop criteria for the selection of textbooks that you may use in identifying a text for classroom use. Those criteria are provided on the sample checklist.

CHECKLIST FOR ANALYSIS OF SCIENCE CURRICULUM MATERIALS

Scale: _____

-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5

Subject _____

Grade _____

1. Concepts appropriate to developmental level of student					
2. Students use processes of science i.e. (observing, measuring, interpreting, predicting, experimenting, model building).					
3. Requires student use of manipulative materials					
4. Student investigations designed to provide organized solutions to problems					
5. Encourages answers to questions based on individual observations					
6. Inquiry is predominant teaching method					
7. Students with low reading ability can be successful					
8. Concepts and material appeal to student interests					
9. Adequacy of teaching aids in teacher's guide					
10. Text is operationally independent of supportive printed materials					

Signature of Evaluator _____

School _____

OKLAHOMA SCIENCE FAIR INFORMATION

The Science Fair program is designed to provide an opportunity for students to display results of individual research. At the same time it allows outstanding science students to come together to share ideas and experiences.

The rewards of participation are not totally academic or social. Students may win cash prizes, merchandise awards, scholarships, medals and certificates, and of course the big award, an expense paid trip to compete in the International Science and Engineering Fair. Many young Oklahoma scientists will win this trip.

If you have students who might like to participate, now is the time to start.

What is A Science Fair Project?

Science fair projects are reports of research that has been done by an individual student. The research and the display must be entirely the work of the student, but this does not mean that students may not seek advice and technical assistance from qualified individuals.

Good science fair projects have the following characteristics in common:

A. The research is well planned.
B. Careful data is collected and presented.
C. A summary of no more than 250 words is prepared which tells the need for this research, how the research was done, what the results were and details the implications of the results.
D. The project is displayed well often using photographs, drawings, charts, graphs, etc.
E. All information presented is organized in such a manner that it is easily understood.

Science Fair Competition

The competition for awards in the science fair program is in some ways similar to athletic competition. Initial competition is at the local or city level where about twenty percent of the competitors are selected to go on to the regional fairs. From each regional fair, projects are selected to enter the state science fair. From regional and state fairs many entries will be selected to go to the International Science and Engineering Fair. There the students will compete against young scientist from the United States and the world. The International fair is truly a very exciting event.

Oklahoma has the fourth largest science fair program in the United States and has always done well at International.

Categories of Competition At The State Science Fair

Students will compete in either the Junior High Division (grades 7-9) or the Senior High Division (grades 10-12) in one of the following categories:

Biological Sciences
Physical Sciences
Earth and Space Sciences
Behavioral and Social Sciences
Engineering
Mathematics
Environmental Sciences

In each category, for each division, awards will be made to the first, second, and third place project.

All exhibitors in grades 9-12 will compete for the trips to the International Science and Engineering Fair.

Special award winner will be selected without consideration of grade level.

Bases for Judging Science Fair Projects

All exhibits entered in the Oklahoma Science and Engineering Fair will be judged on the basis of the following criteria. Exhibitors should study this material carefully.

Judges are to interview finalists before their final decision is made.

I. CREATIVE ABILITY .....Total Points 20

How much work appears to show originality of approach or handling? Judge that which appears to you to be original, regardless of the expense of purchased or borrowed equipment. Give weight to ingenious uses of materials. Consider collections creative if they seem to serve a purpose.

II. SCIENTIFIC THOUGHT .....Total Points 30

Does the exhibit disclose organized procedures? Is there a planned system classification, accurate observation, controlled experiment? Does exhibit show a verification of laws or a cause and effect, or present by models or other methods a better understanding of scientific facts or theories? Give weight to probable amount of real study and effort which is represented in the exhibit. Guard against discounting what might have been added, included, or improved.

III. THOROUGHNESS .....Total Points 25

Score for how completely the story is told. It is not essential that step by step elucidation of construction details be given in working models.

IV. SKILL .....Total Points 10

Is the workmanship good? Under normal working conditions, is the exhibit likely to demand frequent repairs? In collections, how skilled is the handling, preparation, mounting or other treatment?

V. CLARITY.....Total Points 10

In your opinion, will the average person understand what is being displayed? Are guide marks, labels, descriptions neatly yet briefly presented? Is there sensible progression of the attention of the spectator across or through the exhibit?

VI. DRAMATIC VALUE .....Total Points 5

Is this exhibit more attractive than others in the same field? Do not be influenced by "cute" things, lights, buttons, switches, cranks, or other gadgets which contribute nothing to the exhibit.

Techniques of Judging

Techniques of judging the Oklahoma Science and Engineering Fair will be determined by a joint committee composed of representatives from the judges and members of the Oklahoma Science and Engineering Fair Committee.

RULES FOR EXHIBITORS IN THE
OKLAHOMA SCIENCE AND ENGINEERING FAIR

1. All exhibitors will pay a $2.50 entry fee which will cover the cost of the awards banquet. Additional banquet tickets may be purchased at check-in-time.
2. All exhibitors must be certified by the Director of the district fair in which they participated.
3. No more than one individual exhibit may be entered by each exhibitor.
4. All work on the project must be done by the exhibitor, however, any adult may advise. Adults must not do any of the experimentation; build, make, write, print or type any part of the exhibit or report.
5. No exhibit may be displayed that is an exact duplicate of an exhibit displayed by the student any previous year.
6. The exhibitor must supply all materials, tools and equipment for the installation of his project.
7. Each project must be accompanied by a 250 word summary of the work done.
8. All names or other identification marks, except those assigned by the fair director must be removed from both the exhibit and the written report.
9. . The exhibit must not exceed 30 inches from front to back and 48 inches from side to side. Projects may be no more than 12 feet high.
10. No live vertebrates may be exhibited.
11. All exhibits which require electrical power must be designed to operate on 110 volts AC.
12. No explosive, inflammable or poisonous chemicals may be used. No open flames will be allowed.
13. Exhibitors must stand by their projects during the judging.

For more information concerning Regional Science Fairs and the State Science Fair contact:

Oklahoma Science and Engineering Fair, Director
Department of Science Education
East Central University
Ada, OK 74820

Science Specialist
State Department of Education
2500 N. Lincoln
Oklahoma City, OK 73105

SKILLS NEEDED TO READ SCIENCE TEXTS

Premise: Science is a natural vehicle through which reading skills can be improved. Reading skills necessary to understand science content should be taught as an integrated part of every science lesson. The skill(s) to be emphasized will depend upon the nature of the lesson and the sophistication of the student. One quick test of the student's ability is to ask them to read aloud. If they miss more than ten words out of 100 the reading level of the material is too high.

Point out to students the unique need in science for specific reading skills and give them practice as part of the assignment.

Some reading skills to emphasize are:

1. Skill to vary the rate of reading according to the purpose of the reader and the nature of the content
2. Skill in ability to read and follow directions accurately
3. Skill in ability to read for exact meaning, stress main ideas and supporting details
4. Skill in ability to organize ideas obtained from reading
5. Skill in ability to make comparisons
6. Skill in ability to draw conclusions
7. Skill in ability to develop vocabulary from content
8. Skill in ability to understand formulas and scientific symbols
9. Skill in ability to gain accurate information from graphic aids
10. Skill in using parts of a book
11. Skill in locating sources of information.

MATERIALS FOR THE ELEMENTARY SCIENCE PROGRAM

Things to measure with
- calipers
- rulers
- yardsticks
- string
- yarn
- paper ticker tape
- measuring tape
- ribbon
- cups
- boxes
- beans
- trundle wheel
- range rods
- medicine cups
- measuring spoons
- measuring cups
- protractors
- thermometers

Things to build with
- blocks
- clay
- drinking straws
- wood scraps
- tin-can scraps
- cardboard
- cloth
- paper
- wire screening
- junk
- Geo Blocks, A-Blocks Color Cubes, Pattern Blocks

Things to use as plugs
- modeling clay
- wood
- rubber stoppers
- cork stoppers
- paper
- cotton

Things to grow things in
- babyfood jars
- paper or plastic cups
- milk cartons
- clean used lab culture dishes
- dirt
- peat moss
- vermiculite
- sand
- cotton
- paper towels
- boxes
- blotting paper
- buckets
- plant pots
- plastic bags

Tools to have around
- wire clippers
- files
- pliers
- screwdrivers (regular and Phillips)
- saws
- drills
- awls
- tin snips
- scissors
- vises
- C-clamps

Things to make drops with
- eyedroppers
- drinking straws
- plastic shampoo bottles
- plastic liquid detergent bottles

Things for cleaning up
- bottle brushes
- brooms
- dustpans and brushes
- mops
- sponges
- liquid soap
- paper towels
- waste baskets
- dish towels
- vacuum cleaners
- newspapers

Things to stain specimens
- methylene blue
- Eosin Y
- iodine
- food coloring
- ink

Things to heat with*
- candles
- Sterno
- bunsen burners
- stoves
- matches
- hot water

Things to hold things or put things into
- babyfood jars
- glass jars
- milk cartons
- margarine containers
- shoe boxes
- egg cartons
- cardboard boxes
- paint pails
- pie tins
- fruit crates
- plastic shampoo bottles
- plastic liquid soap bottles
- paper and plastic cups
- plastic bags

Things to weigh things with
- McGraw-Hill Multi-Purpose Balance

Things to hang things on or with
- adhesive picture hangers
- nails
- cup hooks
- masking tape
- modeling clay
- pendulum frame
- Christmas-tree ornament hangers
- clothespins
- pipe cleaners
- string
- fishline

Things to fasten with
- paper fasteners
- paper clips
- modeling clay
- tacks and pins
- staplers
- clothespins
- pipe cleaners
- rubberbands
- tape

Things to use as molds
- cups
- juice cans
- milk cartons
- egg cartons
- cone cups
- ice-cubes trays
- modeling clay

If you have carpentry skills or access to a school or home shop, you can make:
- animal cages and boxes
- balances
- balancing blocks
- balance board
- balancing fulcrum
- balance shapes
- pendulum frames
- sand sieves

*We do not recommend alcohol lamps

spring scale
kitchen scale
baby scale
balances

Someone who works in a hospital might be able to get for you or order for you:
- adhesive bandage cans
- analysis tubes
- chemical stains
- corks or rubber stoppers
- cover slips
- discarded transfusion equipment (be sure these are clean)
- flexible vinyl tubes
- hose clamps
- medicine cups
- pill vials
- plastic containers
- plastic eyedroppers
- plastic or glass narrow mouth bottles
- plastic petri or culture dishes
- potato dextrose agar
- prepared slides
- slides
- squeeze bottles
- sterilizers
- syringe pumps (These may be difficult to obtain. If you can get them, get the largest size possible. The school nurse is a likely source of disposable hypodermic syringes without the needles. With today's drug problem, even this may be unlikely. Some states require you to obtain a permit for possession of syringes, even before purchase.)
- test tubes

You may be able to get from building contractors or wood-working shops:
- doweling
- floor and wall tiles
- scraps of wood
- wire
- sand tables
- stream tables
- trundle wheels

A trip to the junkyard may yield, among other things:
- clocks
- electric motors
- mixers
- radios
- screening

Fathers may bring home from work materials such as:
- cardboard boxes
- carpenter's supplies
- dental tools
- electronic equipment
- plastic materials
- plumber's materials

From home:
- babyfood jars
- candles
- chicken, meat, or fish bones
- cottage cheese cartons
- egg cartons
- frozen juice cans
- ice cream containers
- jars with screw tops
- margarine tins
- milk cartons
- plastic containers of every shape and size
- plastic detergent bottles
- plastic shampoo bottles
- powders
- seeds
- shoe boxes
- whipped cream containers

From the supermarket, you can get:
- cartons
- fruit crates
- packing materials
- styrofoam fruit and meat trays

THE USE OF THE FIELD TRIP

One of the most common and useful extensions of the classroom is the field trip. The field trip will vary from a few minutes spent in a school year to an extended or distant visit.

The value of any field trip depends upon the extent to which it becomes a real participatory type learning experience. To the participant it should be interesting, adventurous, and involving. The field experience should relate to the total classroom program or to a specific activity which meets the individual's specific needs. The field trip will vary in meeting needs such as involving the participants in an intense study of the site; to introducing and illustrating certain important concepts; to centering the field trip around one specific subject matter field.

The field trip should consist of several parts:

1. Pre-planning - this phase should include a discussion of the principles which will be illustrated by the field trip. Aspects that should be considered are: pre-site visit by teacher, transportation arrangements, travel log and agenda, conduct and rules for all participants, parental permission, objectives for the trip, and general information to administrators, alternate plans, insurance plans . . .

2. The trip itself should be well organized and the participants should have a good, clear understanding that the trip is to be an educational experience. Aspects of the trip that need including are: respect for other's property, protection of participants, appropriate dress, necessary equipment and tools, sampling instructions, provisions for food and water, quiet or central location for discussion. . . .

3. The follow-up portion of the field trip should include an evaluation of the objectives, including a review of what was done and the principles that have been learned. A brief summary report should be provided the administrator.

OKLAHOMA
State Department of Education
State Science Committee

STATE SCIENCE COMMITTEE RECOMMENDATIONS

1. Science instruction should reflect the Central Purpose of American Education, that is to teach the student the ability to think.

2. Science programs and instruction should provide experiences that foster continuous growth in those human qualities upon which a system of values can be based.
3. Curriculum development should involve the total community (students, teachers, patrons, administrators, and consultants) in the continuing activity of setting goals.

Corollary:

(A) Goals should be based on local assessment of needs, resources and priorities.

4. In order to allow science education to make its maximum contribution to the individual a common set of goals should be adopted for all educational levels.
5. A curriculum concerned with the complete education of a student will include science and its relationship with other disciplines.
6. Every child in the public schools of Oklahoma should have the opportunity to experience programs of inquiry in science at each educational level.
7. The heart of science is the processes of inquiry, and modern science education should reflect this view.

Corollary:

(A) As evidenced by the fact that children need to receive inquiry experiences to aid his transition from concrete to formal intellectual operations.

(B) The science curriculum should be designed so that student experiences involvement in the following processes:

a. observing
b. inferring
c. comparing
d. hypothesis formation
e. analyzing
f. synthesizing
g. generalizing
h. predicting
i. classifying
j. evaluating
k. deducing
l. recalling
m. imagining
n. measuring

(C) As a result of science activities and experiences students should demonstrate increasing proficiency in skill development, i.e.,
a. Collecting and presentation of data
b. Interpreting graphs and tables
c. Utilizing techniques and concepts of measurement
d. Applies mathematics to scientific situations
e. Designing experiments and manipulating appropriate materials and equipment.
f. Gathering information from appropriate resources
g. Analyzing for sources of error.

8. Science education experiences should be made available on the basis of student abilities, stages, and needs.

Corollary:

(A) Each science program should be organized in such a manner that it allows for students differences. Laboratory activities may be planned so that students can work through them at their own rate.

9. Consistent with the view of science as inquiry, student-performed laboratory experiences should be the point of emphasis and departure for science instruction.

Corollary:

(A) Teachers should investigate the national programs which are inquiry oriented and use these national programs in place of text-oriented materials.

(B) That the laboratory be used chiefly to offer the student an opportunity to have an active role in an investigation and to find first hand information rather than a place to merely verify information already known by the student.

(C) Until the need for improvement is recognized, a change in the organized science program will never be attempted. It is recommended:

a. that the local situation determine the decision or appropriate action to be taken
b. that the exiting education efforts and performance be appraised,
c. that the combined efforts of teachers, patrons, administrators and consultants be enlisted,
d. that several alternatives be explored as solutions, and
e. that whatever program is decided, it should continually be evaluated and adjusted or revised.

10. All classrooms utilized for science education should contain equipment, supplies, and facilities to adequately support a process-approach, inquiry-oriented, a laboratory and activity-centered oriented science program.
11. A portion of each school's resources should annually go for curricular exploration in science education.
12. The evaluation strategies and instruments should be consistent with a process approach, inquiry-oriented, laboratory and activity-centered science program.
13. All teacher education programs should prepare teachers to conduct process-approach, inquiry-oriented, laboratory and activity-centered science classes for their students.

Corollary:

(A) Preservice and inservice education should set an example by using the criteria in this recommendation in their instruction.

14. Teachers should have an adequate background for the subject area and levels for which they teach.
15. Oklahoma education should reflect that science instruction is as important to all citizens as any other instructional area and not of value only to potential scientist.